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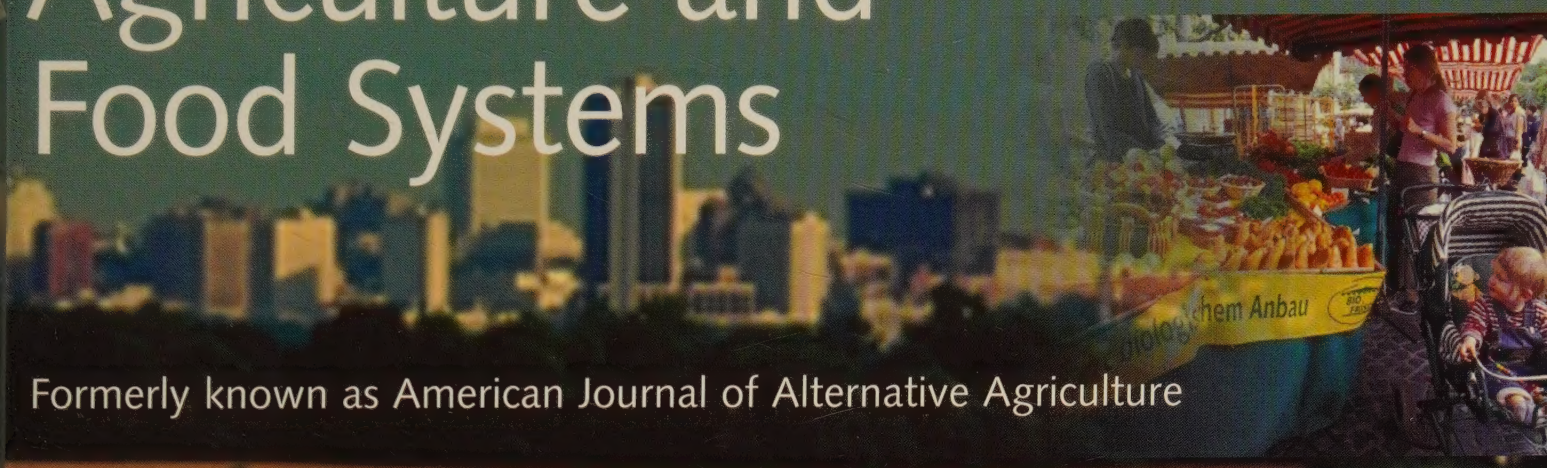

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Renewable Agriculture and Food Systems provides an international forum for original research and review articles on the biological, physical, social science, and policy aspects of alternative agriculture and food systems, focusing on the effective use of renewable resources and biodiversity in agro-ecosystems. The journal particularly welcomes multidisciplinary, holistic, systems research that addresses the multiple challenge of economically meeting basic human needs for food, fiber, and energy while maintaining essential natural and environmental resources.

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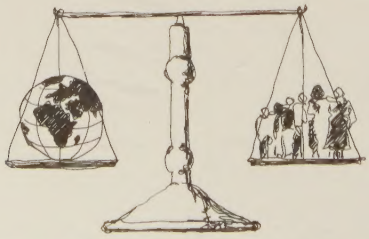

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Cropping systems for the Southern Great Plains of the United States as influenced by federal policy

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Abstract

The majority of cropland in the rain-fed region of the North Central District of Oklahoma in the US is seeded with winter wheat (*Triticum aestivum*) and most of it is in continuous wheat production. When annual crops are grown in monocultures, weed species and disease agents may become established and expensive to control. For many years prior to 1996, federal policy provided incentives for District producers to grow wheat and disincentives to diversify. In 1996, the Federal Agriculture Improvement and Reform (FAIR) Act (Freedom to Farm Act) was instituted, followed by the Farm Security and Rural Investment Act (FSRIA) in 2002. The objective of this study was to determine the impact of FAIR and FSRIA programs on crop diversity in the North Central District of Oklahoma. The economics of three systems, monoculture continuous winter wheat, continuous soybean (*Glycine max*) and a soybean–winter wheat–soybean rotation, were compared using cash market prices (CASH), CASH plus the effective loan deficiency payments (a yield-dependent subsidy) of the FAIR Act of 1996, and CASH plus the effective loan deficiency payments of the FSRIA of 2002. We found that the loan deficiency payment structure associated with FAIR provided a non-market incentive that favored soybean. However, under provisions of the 2002 FSRIA, the incentive for soybean was adjusted, resulting in greater expected returns for continuous wheat. Due to erratic weather, soybean may not be a good alternative for the region. Research is needed to identify crops that will fit in a rotation with wheat.

Key words: wheat, soybean, crop rotation, FAIR, FSRIA, economics

Introduction

Government programs have influenced crop production in the Southern Great Plains since the 1930s[1]. Voluntary acreage control programs were first implemented for wheat as a result of the Agricultural Adjustment Act of 1933[2]. The Agricultural Adjustment Act of 1938 provided for wheat acreage allotments that were allocated to individual farms based upon planting history. Wheat acreage allotments were included in 1956 and 1961 legislations.

A national wheat referendum was conducted in May 1963. Producers were given the opportunity to vote for a mandatory control program designed to restrict wheat production to a level that would result in relatively high prices and reduced government cost. Some farm organizations and producer groups advocated a 'yes' vote that they argued would benefit family farms and enhance stability. Other organizations encouraged their members to vote 'no'. They argued that a 'no' vote would reduce the role of government and provide farmers the 'freedom to farm'[3]. Over a million producers participated in the 1963 referendum with 48% voting 'yes' for mandatory controls and 52% voting against mandatory controls and for what had been advertised as the 'freedom to farm'. Contrary to what some had expected, the majority 'no' vote did not terminate government involvement in wheat production.

Government involvement continued and many subsidy payments were based upon the farm's wheat base acres and base yield. Base acres were valuable and farmers had an economic incentive to convert as many acres as possible to wheat base. In 1977, legislation changed the acreage base for wheat from historical allotments to a percentage of current plantings. In 1981, the acreage base was reestablished depending upon acres planted in prior years. Over

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time, the government programs provided an incentive for farmers in the Southern Plains to use as much cropland as possible to produce continuous monoculture winter wheat (*Triticum aestivum*).

When an annual crop is grown year after year in the same field, weed species that are adapted to the environment may flourish and become difficult to control. Diseases that infect the crop may become established in the field and become a persistent problem. Furthermore, if crop residue is retained on the soil surface, disease organisms may bridge from old crop residue to the new crop.

Federal farm programs may simultaneously encourage and discourage continuous monoculture wheat. Historically, wheat producers in the Southern Plains used conventional tillage to manage weed and pest problems. When problems became severe, they would use a moldboard plow to bury residue and weed seeds. However, beginning in 1985, the Food Security Act included what became known as the conservation compliance requirement[4,5]. The Act mandated that, by 1995, farmers who farmed land classified as highly erodible were required to implement conservation compliance plans as a condition for retaining eligibility for subsidy payments. To fulfill the conservation compliance requirements, for many soils in the region, farmers were required to maintain some surface residue, a requirement that in effect limited moldboard plowing. Thus, strict adherence to conservation-compliance requirements would exacerbate the weed and disease problems of a monoculture.

Diversification of cropping systems can be achieved by rotating different species over years within a given field. It has been hypothesized, and demonstrated in some locations, that diversity provided by crop rotations may help manage nutrient cycling and reduce weed, insect, pathogen and nematode problems[6]. Young and Painter contend that the genetic diversity that results from crop rotations is an important means to sustainable crop production[7]. Smith and Young found that in at least one region of the country, US agricultural policy might have influenced the level of crop diversification[8].

Throughout the world, crop rotations are used to manage weed and disease problems. For example, in the US Corn Belt corn (*Zea mays*)–soybean (*Glycine max*) rotations are common. Crop rotations enable producers to break weed and disease cycles associated with monocultures. When these cycles are broken, yields may increase and producers may be able to deliver a higher quality crop with less dockage. In long-term studies, scientists have found that when corn is grown in a 2-year rotation with soybean, weed control options are increased and average corn yield per acre increases relative to monoculture corn[9].

The Federal Agricultural Improvement and Reform (FAIR) Act of 1996 permitted farmers greater flexibility in crop selection. Thirty-three years after the 1963 wheat referendum, in which the majority of wheat producers voted for less government involvement, the 'freedom to farm' slogan was revived and became synonymous with the 1996 FAIR Act. It was promoted as legislation that would enable farmers to base planting decisions on market incentives rather than commodity programs. For farmers with base acres, most subsidy payments made after 1996 did not depend upon the crop grown, yield, or market price. This was a major departure from prior legislation. The incentive to build and maintain wheat program base acres was removed and farmers were free to try other crops, including crop rotations on wheat base acres, without jeopardizing subsidies. However, limited historical data were available comparing the economics of alternative crops and cropping systems for the region. In fact, the search for an economical alternative crop to rotate with wheat in the Southern Plains was hampered by government program requirements. Prior to 1996, researchers made little effort to find an alternative because they had little incentive to do so. Moreover, agencies that funded wheat production research had little interest in funding research for a competing crop.

Historical Cropping Patterns

While the agronomic, environmental and aesthetic benefits of species diversification and crop rotation have been espoused, the reality is that the vast majority of cropland in the rain-fed region of the Southern Great Plains is seeded to winter wheat and most of that land is in continuous wheat production. The North Central District is one of nine Agricultural Statistics Districts in Oklahoma, as defined by the United States Department of Agriculture (USDA). It includes approximately 1 million ha of cropland and in most years accounts for more than 35% of the wheat grain produced in the state.

In 1995 approximately 95% of the land seeded to annual crops in the North Central District of Oklahoma was seeded to continuous monoculture winter wheat (Table 1)[10,11]. Table 1 and Figure 1 show cropland use in the North Central District for the years 1995, 1999 and 2002, allowing comparison of cropped acres prior to and after implementation of the 1996 legislation. These data indicate that in 1995, 870,093 ha were seeded to wheat in the District. By 1999, land seeded to wheat declined by 101,174 ha (12%) to 768,919 ha. Land seeded to soybean (*G. max*) and sorghum (*Sorghum bicolor* L. Moench) increased by 71,550 ha. Most of the remaining 30,000 ha, removed from wheat production, were reallocated to the production of hay (12,141 ha), cotton (*Gossypium*) (8033 ha) and rye (*Secale cereale*) (4452 ha).

The Conservation Reserve Program was established in the 1985 Farm Bill. Cropland was removed from production under 10-year contracts for which landowners received an annual rental payment from the federal government. Some of these contracts expired between 1995 and 1999. Most of the 13,700 ha that exited the Conservation Reserve Program during this time period were retained in perennial grass for pasture (Table 1).

Table 1. Cropland use in the North Central District of Oklahoma, USA (Alfalfa, Garfield, Grant, Kay, Major, Noble, Woods and Woodward counties) in 1995, 1999 and 2002 (ha).

Land use	1995	1999	2002
Annual crops			
Wheat (*Triticum aestivum*)	870,093	768,919	728,450
Rye (*Secale cereale*)	21,854	26,305	30,352
Sorghum (*Sorghum bicolor* L. Moench)	16,188	46,945	36,423
Oats (*Avena sativa*)	4,047	4,047	6,070
Soybean (*Glycine max*)	3,723	44,516	20,235
Corn (*Zea mays*)	1,619	3,642	8,296
Cotton (*Gossypium*)	384	8,418	5,342
Total annual crops	917,908	902,792	835,168
Conservation Reserve Program	53,095	39,395	40,633
All hay	72,845	84,986	84,176
Total used for crops, Conservation Reserve Program and hay	1,043,847	1,027,173	959,977
Estimated change in cropland use for pasture	–	16,675	67,195

Source: Oklahoma Agricultural Statistics Service; USDA.

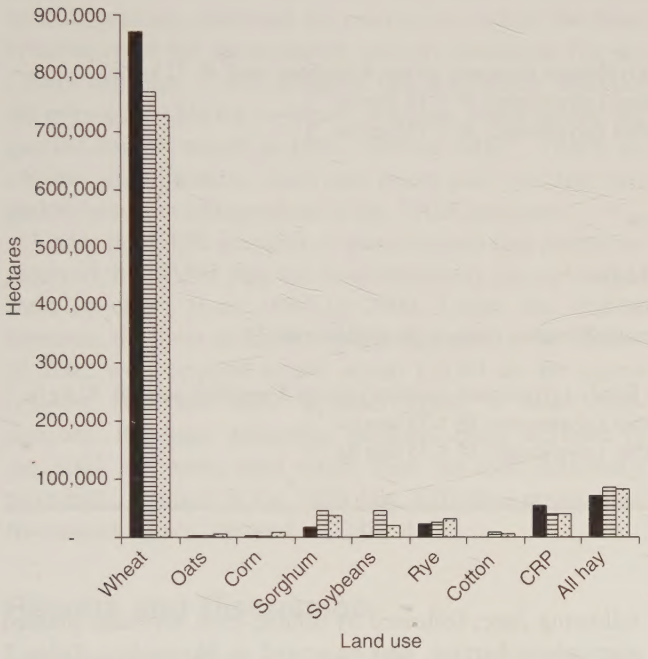

Figure 1. Land used for annual crops, Conservation Reserve Program (CRP) and hay in the North Central District, Oklahoma (Alfalfa, Garfield, Grant, Kay, Major, Noble, Woods and Woodward counties) in 1995 (■), 1999 (▤) and 2002 (▨) (ha).

The data in Table 1 and Figure 1 indicate that farmers in the North Central District responded to a limited extent to the flexibility afforded by the 1996 legislation. It is likely that land marginally suited for winter wheat production was returned to pasture, while a portion of the remaining cropland was planted to soybean and sorghum. Land seeded to soybean increased from 3723 ha in 1995 to 44,516 ha in 1999. However, by 2002 the area seeded to soybean declined to 20,235 ha. It is not clear why this occurred. Producers may have determined that soybeans were not a more profitable alternative for the District, or the relative profitability of soybean may have changed as a result of the 1996 federal legislation.

Most subsidy payments made after 1996 to farmers who have wheat base acres do not depend upon crop grown, yield or market price. Farmers are not required to grow the base crop—hence 'freedom to farm'. The subsidies are based upon the farms' historical base acres and historical base yield. However, there is one exception. Loan deficiency payments depend upon the quantity of crop produced. National average loan rates were set in the farm bill. Loan rates for a given county are established relative to the national rate by the USDA and depend upon marketing patterns and transportation distance from the county to market locations. If the market price of wheat is less than the established loan rate, a producer may apply for and receive a loan deficiency payment, calculated as the difference between the local loan rate and the local market price multiplied by the number of bushels produced. In effect, the loan rate is a price floor on actual production. Under the 1996 FAIR Act, the 2001 national loan rates were $\$0.095\,kg^{-1}$ for wheat and $\$0.193\,kg^{-1}$ for soybean. Under the 2002 Farm Security and Rural Investment Act (FSRIA), the national loan rate was increased by 8.5% to $\$0.103\,kg^{-1}$ for wheat but decreased by 4.9% to $\$0.184\,kg^{-1}$ for soybean[12].

The objective of this study was to compare the economics of monoculture continuous winter wheat relative to that of two potential alternatives for the North Central District of Oklahoma, located in the traditional wheat production region of the Southern Great Plains. The two alternatives include continuous soybean and a crop rotation that includes winter wheat and soybean. The economics of the three systems were compared using: (1) cash market prices (CASH), (2) CASH plus the effective loan deficiency payments of the FAIR Act of 1996, and (3) CASH plus the effective loan deficiency payments provided by the FSRIA of 2002. An additional objective was

Table 2. Chronology of field operations for three alternative cropping systems.

Month	Field operation
Continuous wheat	
July	Disk tillage
September	Chisel tillage
	Apply 82-0-0 @ 86 kg ha^{-1}
	9″ Sweep tillage
October	Drill wheat seed @ 101 kg ha^{-1}
February	Apply 33-0-0 @ 56 kg ha^{-1}
March	Apply herbicide [0.04 liter ha^{-1} Amber (triasulfuron) and 1.2 liter ha^{-1} Rhonox (MCPA)]
June	Harvest wheat
Continuous soybean	
March	Disk tillage
May	Field cultivator tillage
June	Drill Roundup Ready (glyphosate resistant) group 5 soybean seed @ 52 kg ha^{-1}
	Apply herbicide [Dual (metolachlor) @ 1.5 liter ha^{-1}]
July	Apply herbicide [Roundup (glyphosate) @ 1.75 liter ha^{-1}]
November	Harvest soybean
Soybean–wheat–soybean (2-growing seasons)	
March	Disk tillage
April	Field cultivator tillage
	Drill Roundup Ready (glyphosate resistant) group 4 soybean seed @ 52 kg ha^{-1}
	Apply herbicide [Roundup (glyphosate) @ 1.75 liter ha^{-1}]
May	Apply herbicide [Roundup (glyphosate) @ 1.75 liter ha^{-1}]
September	Harvest soybean
	Disk tillage
	Apply 82-0-0 @ 86 kg ha^{-1}
	9″ Sweep tillage
October	Drill wheat seed @ 101 kg ha^{-1}
February	Apply 33-0-0 @ 56 kg ha^{-1}
March	Apply herbicide [Express (tribenuron methyl) @ 0.02 liter ha^{-1}]
June	Harvest wheat
	Plant (no-till) Roundup Ready (glyphosate resistant) group 5 soybean seed @ 52 kg ha^{-1}
	Apply herbicide [Roundup (glyphosate) @ 1.75 liter ha^{-1}]
July	Apply herbicide [Roundup (glyphosate) @ 1.75 liter ha^{-1}]
November	Harvest soybean

to determine the impact of FAIR and FSRIA programs on crop diversity in the region.

Materials and Methods

Data were obtained from a study conducted from 1997 through 2000 at the North Central Research Station in the North Central District at Lahoma, Oklahoma, under rainfed conditions. Four replications of each of the three cropping systems were evaluated: continuous wheat, continuous soybean and a soybean–wheat–soybean 2-year rotation. For the continuously cropped systems, winter wheat was planted in mid-October and harvested in June, while soybeans were planted in May and harvested in November. For the soybean–wheat–soybean rotation, soybeans were planted in April and harvested in September; followed by winter wheat planted in October and harvested the following June; followed by double-crop soybeans planted after wheat harvest, and harvested in November. Table 2 includes a listing of field operations for each of the three systems. Wheat and continuous soybean were planted using conventional tillage, which involved disking, chiseling and field cultivating. Double-crop soybeans were planted with a no-till row crop planter. All yields were measured after threshing and drying to bring the seeds to uniform moisture content. Mean annual yields across replicates are reported in Table 3.

Rainfall in the region is erratic. Total rainfall during the first 2 years of the study was above average. Annual rainfall was 140% of the long-term average in 1998 and 162% of the long-term average in 1999. The weather during the 1998 and 1999 growing seasons was abnormally favorable for soybean production, and yields were above average in both years (Table 3). In 2000, annual rainfall was 107% of the long-term average. However, no rainfall occurred

Table 3. Yields by cropping system for 1998, 1999 and 2000 (kg ha^{-1}).

Year	Crop rotation				
	Continuous soybean	Continuous wheat	Soybean in rotation	Doublecrop soybean	Wheat in rotation
1998	2297	3742	2912	928	3705
1999	2528	4036	2320	1087	4023
2000	984	3074	1413	397	2986
Average	1936	3617	2215	804	3571

in August and September of 2000, critical months for soybean production, and yields were below the average for the 3-year study (Table 3).

A representative farm approach was used to estimate differences in cost among the various systems, including machinery requirements, ownership and operating costs[13,14]. Enterprise budgeting was used to determine annual revenues, costs and net returns for each of the three systems under the three market (policy) situations. For the CASH situation, it was assumed that a producer received the average CASH for soybeans or winter wheat during the specific harvest month in 1998, 1999 or 2000[15]. This is an obvious simplification, since cash prices paid over the time period were not independent of the FAIR program.

Under the FAIR scenario, it was assumed that producers received the CASH plus the loan deficiency payments that were in effect from 1998 to 2000. Under the FSRIA scenario, the loan deficiency payments set by the FSRIA of 2002 were applied to the actual CASH in the region between 1998 and 2000. In other words, to make comparisons, the loan deficiency payment rates included in the 2002 law were used rather than the loan deficiency payments included in the 1996 law. Effective prices used for budgeting are reported in Table 4.

Table 4. Commodity prices over years and across programs ($ kg^{-1}).

Year	Wheat	Soybean
Cash (CASH) market prices		
1998	0.10	0.20
1999	0.09	0.17
2000	0.09	0.17
Cash (FAIR) plus loan-deficiency payment		
1998	0.10	0.21
1999	0.09	0.21
2000	0.09	0.21
Cash (FSRIA) plus loan-deficiency payment		
1998	0.10	0.20
1999	0.10	0.19
2000	0.10	0.19

Results and Discussion

Economic comparison of the three rotations evaluated showed mixed results across years. Net returns for each system, year and program scenario are reported in Table 5. The average net return and coefficient of variation are also reported. Greatest net return was realized for soybean–wheat–soybean in 1998, continuous soybean in 1999 and continuous wheat in 2000.

Continuous wheat was the only system that had positive net returns every year for each program scenario. Under all program scenarios, both continuous soybean and the soybean–wheat–soybean rotation outperformed continuous wheat in 1998 and 1999. This is due to the fact that the weather during the 1998 and 1999 growing seasons was abnormally favorable for soybean production. However, both systems that included soybean showed substantial losses in 2000, a year in which rainfall was more consistent with historical averages.

On average, continuous wheat earned $7 ha^{-1} more than the soybean–wheat–soybean rotation and $26 ha^{-1} more than continuous soybean under the CASH scenario. Given the FSRIA and CASH scenarios, relative rankings for the three cropping systems were the same. However, average earnings for continuous wheat were $7 ha^{-1} more than soybean–wheat–soybean and $33 ha^{-1} more than continuous soybean under FSRIA.

The 1996 FAIR legislation changed the relative economic rankings of the three cropping system alternatives. On average, the soybean–wheat–soybean rotation earned $10 ha^{-1} more than continuous soybean and $23 ha^{-1} more than continuous wheat. While the 1996 FAIR legislation was purported to enable farmers to base cropping decisions on market incentives, the loan deficiency payment structure associated with FAIR provided a nonmarket incentive that favored soybean relative to wheat in the District. With the 2002 FSRIA legislation, this nonmarket incentive was removed by increasing the national loan rate by 8.5% for wheat and decreasing the loan rate by 4.9% for soybean.

The variability in net returns, as reflected in the coefficients of variation, is greater for systems that include soybean relative to continuous wheat. Under both the

Table 5. Net returns to land, labor and management ($\$ ha^{-1} yr^{-1}$).

System	Program	1998	1999	2000	Average	Coefficient of variation
Continuous soybean	CASH	167	130	−88	70	2.0
	FAIR	183	233	−54	121	1.3
	FSRIA	167	201	−66	101	1.4
Continuous wheat	CASH	132	108	48	96	0.5
	FAIR	132	136	55	108	0.4
	FSRIA	147	173	83	134	0.3
Soybean–wheat–soybean crop rotation	CASH	201	111	−44	89	1.4
	FAIR	219	184	−10	131	0.9
	FSRIA	209	181	−7	127	0.9

CASH and FSRIA scenarios, continuous wheat exhibited greater expected net returns and lower variability than either of the soybean systems. However, under the FAIR scenario, expected net returns were greater for the two systems that included soybean.

Conclusions

The 1996 FAIR Act was promoted as legislation that would allow and encourage farmers to base planting decisions on market incentives rather than government programs. However, since the loan deficiency payments remained coupled to production, it was possible for FAIR to distort market incentives. The results of this analysis indicate that the 1996 FAIR Act promoted crop diversity in the Southern Great Plains by improving the economics of continuous soybean relative to that of continuous wheat. Conversely, the 2002 FSRIA changed the relative economics to favor winter wheat, thereby providing a disincentive to crop diversity in the region. Farmers respond to economic incentives. Smith and Young found that in at least one region of the country, US agricultural policy might have influenced the level of crop diversification[8]. Results of this study corroborate the impact of public policy on cropping patterns.

Historical data indicate that producers responded to the 1996 and 2002 legislation by converting some wheat base acres to permanent pasture. Data are not available to compare the relative economics of continuous wheat with pasture. Additional research would be required to determine if marginal cropland that was in wheat production as a result of federal policies that encouraged base building was converted to pasture.

Monoculture continuous wheat became the dominant cropping system in the North Central District of Oklahoma, in part, because of government programs that provided incentives to build wheat base acres. While the 1996 FAIR Act provided the flexibility and economic incentive for crop diversification and movement away from monoculture wheat, farmers had little information on viable options. Since farmers did not grow alternative crops, and research funds depend to some extent on current cropping patterns, little research had been conducted to evaluate alternatives. This is especially problematic because field studies that include crop rotations are expensive and ideally should be replicated over many years. Due to the erratic weather and current market incentives under the 2002 FSRIA, it appears that soybean is not a good alternative for the region.

Government programs that link subsidy payments to the acres grown of specific crops and to the level of crop production have had a substantial effect on cropping patterns. The 1996 and 2002 programs decoupled most subsidy payments from specific crops. However, the subsidies are still linked to the land input. Benefits from the subsidy programs accrue to land and are reflected in land values and cash rents[16,17]. If the intent of policy makers is to subsidize farm families, basing subsidies on farm family income rather than on land (acres) may be more cost effective.

Decoupling has provided greater flexibility in crop selection and may ultimately enhance rural landscape diversity. However, diversification requires crops or cropping systems that are economically competitive with the current cropping system. Research is necessary to identify economically competitive alternatives. For crop diversification to expand in northern Oklahoma, research is needed to identify a crop or combination of crops that will fit in a rotation with wheat.

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Extending agroecology: Grower participation in partnerships is key to social learning

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Abstract

The extension of agroecology requires an alternative extension pedagogy. Agroecology is more than merely the promotion of new technologies or practices, but rather a fresh understanding of how to optimize the configuration of biological and technological components of farming systems informed by ecological principles. This necessarily requires a shift in roles among growers and extensionists so that they can actively participate in networks of social learning. Agro-environmental partnerships have emerged in California as the primary strategy for extending alternative, agroecological knowledge in conventional agriculture. Partnerships are an intentional, multi-year relationship among at least growers, a growers' organization, and one or more scientists to extend agroecological knowledge and protect natural resources through a field-scale demonstration. Partnerships have been particularly successful in perennial crop farming systems, and have played critical roles in helping California's almond and pear growers to reduce organophosphate use by over 75%. This study provides a cross partnership comparison of grower participation in partnerships and proposes a five-part typology to rank this.

Key words: agroecology, agricultural extension, agricultural partnerships, farmer participation, social learning, social networks, California

Introduction

Renewable agriculture requires an alternative approach to extension. Most extension services have operated with a 'Transfer of Technology' paradigm, when in fact it is these technologies that are used in unsustainable ways[1]. Most agricultural extension efforts have focused on increasing the adoption of new technologies to increase yields, with little regard for the impact new technologies and practices have on the entire farming system. Yet, simply inserting ecologically based practices into conventional agricultural extension systems has a very poor record of adoption[2,3]. Researchers and practitioners are increasingly articulating an agroecological framework for sustaining yields while conserving natural resources upon which agricultural production depends[4,5]. As an alternative agricultural paradigm, agroecology rests on alternative epistemological assumptions[6]. Successfully generating and exchanging agroecological knowledge requires a shift in actors' roles and participation.

Researchers have devoted considerable attention to the importance of farmer participation in agricultural extension in the developing world, focusing on the needs and perspectives as the end users of new knowledge[7–9]. To implement agroecological strategies, growers, extensionists and scientists have to conduct research and extension together through social learning processes, often referred to as 'partnerships'[10]. Most social science research into grower participation has been done in the developing world, although initiatives at the Wageningen Agricultural University in The Netherlands are an important exception to this[11]. Their work indicates that even in advanced capitalist agriculture, growers must actively participate in these social learning processes, and that these are more effective when organizations of growers facilitate a re-thinking of farming systems in light of specific, local ecological conditions[12]. This requires a fresh approach for growers accustomed to passively receiving expert knowledge from others, and for extension agents accustomed to the role of expert.

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Agricultural extension is in crisis across many countries, chiefly due to trends toward privatization[13–15]. In the US, public extension services are institutionally located in agricultural universities. Extension service budgets in the states of Arizona, Oregon, Washington, Maryland, Texas, Colorado, Oklahoma and Alabama have all been cut during the past 3 years. Georgia has lost over 50% of its extension service. Likewise, the University of California Cooperative Extension (UCCE) service suffered serious budget cuts: 25% between 2001 and 2003. In addition, restructuring of professional incentives for extensionists more toward research has further removed them from field-based educational activities. Extension specialist McDowell[16], who has worked for decades in the US Cooperative Extension service, describes his institution as suffering from an 'identity crisis'. He notes a national pattern of agricultural interest groups 'taking extension hostage', meaning they have persuaded extension services to provide technical support for profitable yet resource polluting practices, a strategy that is unsustainable ecologically as well as socially and politically.

The publication of the National Research Council's Alternative Agriculture[17] accelerated the development of alternative models of extension in several regions of the US, based on co-learning and knowledge exchange rather than technology transfer. These initiatives explicitly assume that new practices can be developed that conserve natural resources and enhance grower economics, that scientists and growers have to learn from each other, and that knowledge exchange is accelerated through farm-scale joint research[18]. Prominent examples of these have been the Practical Farmers of Iowa[19], a team approach to extension in Wisconsin[20], soil conservation in Washington state[21], and California's agro-environmental partnerships. All of these evince a shift in roles—in social relations between growers, extensionists and scientists—to extend renewable agriculture and overcome the constraints of conventional extension pedagogies.

Over the past 15 years, agro-environmental partnerships have become the primary vehicle for facilitating agro-ecological strategies in conventional California agriculture to address agricultural pollution[22]. Thirty-two partnerships have created networks of growers, scientists and agricultural organizations to extend agroecological knowledge to protect environmental resources, reduce pesticide use and reduce input costs. Agro-environmental partnerships incorporate traditional participants in agriculture, but configure them into intentional and dynamic networks to learn how to optimize ecological relationships in farming systems. Partnerships facilitate social learning among growers, which I define as: participation as a group in experiential research and knowledge exchange to enhance common resource protection[23].

This paper reports original research into the development, impact and social organization of agro-environmental partnerships in California. These represent an innovative, semi-privatized approach to organizing extension activities guided by agroecological principles. Agro-environmental partnerships demonstrate the critical importance of grower participation in social learning about these strategies, and the essential, facilitating role growers' organizations have played in fostering participation. Successfully extending agroecology requires the design of alternative extension pedagogies, based on fostering social networks of active participation in social learning by scientists and growers.

This paper begins with an introduction to California's hyper-specialized agriculture and the implications of this for the practice of agroecology. A description of California's agro-environmental partnerships, and their impacts, follows. The next section describes growers' roles in creating and maintaining these partnerships. The paper concludes by analyzing the social networks that order grower participation in partnerships, and proposing a five-part typology for interpreting their social learning models.

Methods

This paper reports qualitative research into the social relations among partnership participants, and how they negotiated research and outreach activities. Using in-depth interviews among growers, their consultants and scientists, it highlights the critical role of grower agency and participation in partnership viability, although it does not attempt to quantify the impact of these partnerships on growers. It describes reductions in agrochemical usage in several commodities that have hosted the most active partnerships, although it presents no evidence of an exclusive, direct cause/effect relationship of partnership activity on agrochemical decision making by participants.

Three years of field interviews in California provided the data sources for this research. The primary sources of information are semi-structured interviews with 32 partnership leaders. This is supplemented by: personal interviews with 97 other participating growers, managers, scientists and grower organization staff; 13 focus groups with 84 participating growers, extensionists, scientists and grower organization staff; and participant observation at 34 partnership-related meetings. Data from this field work were analyzed and reported more fully in a dissertation[24].

Agroecology in California

Agroecology prescribes agricultural and ecosystem management strategies based on the discipline of ecology, and it marks a convergence between the agricultural and ecological sciences[25]. Fifteen years ago Altieri[26] proposed three chief characteristics of agroecology:

(1) a systems framework of analysis;
(2) a focus on both biophysical and socio-economic constraints on production; and
(3) use of agroecosystem or region as a unit of analysis.

More recently, he has described agroecology as optimizing agroecosystem processes (see Table 1), which

Table 1. Elements of agroecology.

Agroecosystem processes (Altieri[5])	Practices promoted by California's agro-environmental partnerships
Organic matter accumulation and nutrient cycling	Cover crops, application of compost, manures, chipping tree prunings, crop residue management
Soil biological activity	Cover crops, application of compost, manures, crop residue management
Natural control mechanisms (disease suppression, biocontrol of insects, weed interference)	Removing ecologically disruptive agrochemicals from the farming system, bio-diversification to attract and retain beneficial insects, cover crops
Resource conservation and regeneration (soil, water, germplasm, etc.)	Protection of streams with buffer strips, efficient use of irrigation water (no attention paid to genetic resources)
General enhancement of agrobiodiversity and synergisms between components	Managing components of farming systems to capture synergistic benefits

correspond rather well with the practices promoted by California's agro-environmental partnerships[5]. Note that Table 1 only reports the processes which growers and scientists can use as tools in designing farming systems; extending agroecology requires specific adaptation of these processes to local ecological conditions and distinct production systems.

California agriculture is among the most hyper-specialized and commodified in the world[27,28]. For this reason, farmers here prefer the term 'growers'[29]. Most California growers identify themselves primarily by the primary commodity crop they grow (e.g., an almond grower or a winegrape grower), and they purchase virtually all inputs (including many that growers in other places produce on their farm, such as compost). Extension agents also work among a restricted number of crops. Partnerships have thus emerged within the context of commodity-specific social networks. Participants in each partnership build on commodity-specific knowledge, and their consideration of agroecological strategies is restricted to optimizing their commodity-specific farming system. Growers and extensionists conceptualize bio-diversification and attempts to capture synergistic benefits only within the context of monocultural, single commodity production practices.

Agro-environmental Partnerships in California

This section describes the origins of pioneering partnerships and explains why partnerships have been more effective among perennial crops. The agro-environmental partnership model has been the chief strategy for extending alternative, agroecological knowledge in California over the past decade, with over 500 growers, 92 public scientists and extensionists, and 84 private entomologists/crop consultants participating. These growers experimented with agroecological practices on over 9800 hectares, while managing a total of over 97,500 hectares[24]. I define an agro-environmental partnership to be an intentional, multi-year relationship between at least growers, a growers' organization, and one or more scientist to extend agroecological knowledge and protect natural resources through field-scale demonstration. This extension model contains traditional elements and participants, but deliberately configures them to more effectively promote agroecological knowledge. Partnerships create opportunities for actors to negotiate their respective goals for agricultural research, education and production, and they facilitate a more comprehensive response by growers and scientific actors.

The almond Biologically Integrate Orchard Systems (BIOS) partnership is the best-known and most studied partnership in California[30,31]. At the request of two brothers who farmed almonds—one with organic and the other with conventional methods—UCCE extensionist Lonnie Hendrix launched a multi-year, whole-farm comparison documenting the ecological relationships on the organic farm that made it more profitable while dramatically reducing agrochemical use[32]. The non-governmental organization Community Alliance with Family Farmers (CAFF) expanded this into regional programs of field-scale comparisons by groups of growers who conducted on-farm research based on collaboration among growers, private entomologists, CAFF staff and university researchers.

BIOS promoted a holistic, farming systems approach. Instead of substituting one or two ecologically based practices for a harmful technology, BIOS promoted the re-design of farming systems based on agroecological principles, but encouraged the grower to make changes on a timetable of his or her own choice. BIOS helped growers perceive the potential interactions between components of their farming system, and the impact that alternative management practices with one component could have on the overall farming system.

CAFF parlayed BIOS's early and dramatic success in agrochemical reductions into a broader agenda for a change that included state policy initiatives as well as constructive engagement with commodity organizations (marketing orders), such as the Almond Board of California[30]. It proposed BIOS-like partnerships as an alternative model for conducting extension, based on populist and

environmental conservation values. This partnership model has three main components:

(1) a *structure* of local management teams;
(2) a *process* of grower outreach; and
(3) a *goal* of reducing agrochemical use by adopting integrated farming practices[33].

CAFF insisted that what they had demonstrated to be successful in almonds could be replicated for other commodities. The example of BIOS and the advocacy of CAFF stimulated legislators, public agency officials and private philanthropic foundations to fund and create funding programs for a total of 32 partnerships between 1991 and 2003.

Growers who do not wish to transition to organic production have found partnerships to be an attractive way to learn more about alternative practices. The voluntary nature of partnerships facilitates the active contribution of growers and private consultants pre-disposed to experimenting with agroecological approaches. They participate because they think they can cut costs while farming more in keeping with their environmental values. Scientists and extensionists engage in partnerships because their contribution can have a greater impact and they stand to learn from skilled growers. Partnerships enhance or create an interactive network to extend and evaluate alternative practices on a field scale. Partnerships are sufficiently flexible to allow various goals to be pursued in different partnerships, and by different participants within the same partnership.

The entrance of growers' organizations such as CAFF and the Almond Board into extension activities is a remarkable new development in California agriculture, and is one factor distinguishing the agro-environmental partnership model from conventional extension models using integrated pest management (IPM) strategies[24]. California growers have always been highly organized, and have funded university research for many years, but not extension activities. The combination of the retreat of public extension services plus increasing environmental regulatory pressure has induced these organizations to help growers develop more resource conserving practices.

The two primary public funding programs have been the University of California's Biologically Integrated Farming Systems (BIFS) and the Department of Pesticide Regulation's Pest Management Alliance (PMA) program. They sponsored ten and eight partnerships respectively. The Pew Charitable Trust funded partnerships in California and elsewhere, and later established the Center for Agricultural Partnerships that funded two additional projects in California. Yet growers or growers' organizations initiated nine partnerships, independent of these major funding programs[24]. This indicates the degree of grower interest in alternative practices.

The 32 partnerships have addressed alternative production systems in 16 crops. Perennial crops, perennial crop growers and organizations of perennial crop growers all appear to be more disposed to partnership activities. Three-quarters of all partnerships have been in perennial crops, and only perennial crops have hosted two or more partnerships. Over half the partnerships have been in just five crops (winegrapes, walnuts, pears, almonds and prunes). Several factors favor partnership development in permanent crops: the cropping system, social relations within the commodity; and economic pressures on California agriculture.

The perennial character of these crops is very important. Perennial crops do not require the same degree of disturbance that annual crops do, and biocontrol strategies have been relatively more successful in them. Perennial crop growers have added incentives to invest time in learning about perennial crops because they represent a multi-decade investment of capital and labor.

Secondly, perennial crop growers have a long history of cooperative organization, more so than growers who grow annual crops or raise agricultural animals[29]. Agro-environmental partnerships build on this tradition. Perennial crop growers have a long history of successful commodity organizations and cooperative marketing efforts, rewarding collective activities. This is true across most commodities, and especially true with local winegrape organizations. Commodity organizations exist at the pleasure of a majority of growers, and have to continually prove their worth to their members to justify the assessments they collect from growers on each pound of crop. Partnerships are a new way so that they can add value to their organization and further strengthen grower support for them.

Thirdly, over the past few decades, there has been a trend in California agriculture away from low value extensive crops toward high investment perennial crops[34]. This has been driven by increased demand for fruit and nut crops plus growers' needs to capture improved returns per acre from their land. This has resulted in attracting somewhat more educated and entrepreneurial growers, with new capital and expertise, and in some cases, more education. This is especially true in almonds and winegrapes, and to a lesser extent in walnuts.

Assessing the Impact: Examples from Pioneer Partnerships

Agro-environmental partnerships impact a commodity's practices through three general stages: discovery, agronomic feasibility and economic viability. The first stage consists of initial research into why some growers have had success with agroecological methods. Hendricks's whole farm comparison study in the late 1980s performed this function in the almond farming system, but some partnerships have not been able to move beyond this stage because a system of alternative practices has not yet been assembled for that crop.

The second stage demonstrates the agronomic viability of new methods. Most partnerships have developed effective practices, but they require more (expert

monitoring) labor or are more expensive. Growers participating in partnerships at this stage are motivated to learn about new methods when they are subsidized or supported, but few are willing to spend much more for them once the partnership has ended.

The third stage depends on widespread circulation of knowledge about practices among growers of a specific commodity, after they have been demonstrated to be economically viable. The more successful partnerships have created manuals to help growers make the transition to an alternative farming system. CAFF worked with the Almond Board to create the Almond BIOS manual[35]. The Lodi Woodbridge Winegrape Commission developed a manual to assist its member growers in understanding and managing winegrape farming systems under local conditions[36]. A statewide organization, the California Association of Winegrape Growers, built upon and expanded this approach[37]. The prune partnership assembled its findings into a manual as well[38].

During the 1990s, California's annual use of agricultural pesticides fluctuated around 200 million pounds, roughly a quarter of the US total[39–43], so for political reasons at the very least, partnerships have documented pesticide reduction as a result of their activities. Four commodities evince significant commodity-wide progress in pesticide reduction, as documented by California's Pesticide Use Report database, attributable in part to agro-environmental partnership activities: pears, almonds, stone fruit and winegrapes[44].

These four commodities have had the most active, far-reaching and successful partnerships. The first three have documented dramatic reductions in organophosphate (OP) pesticide use. Agro-environmental partnership activities are not the only reason for pesticide reductions in these commodities. Pesticide resistance, weather and the economics of new 'softer' pesticides are also critically important factors, but partnerships have helped all of these commodities and provided the social relations necessary to support widespread learning about alternative practices and how to use them successfully.

The California almond industry has documented the greatest volume reduction of OP use, from almost 500,000 pounds in 1992 to just over 100,000 pounds in 2000. Much of this reduction is attributed to growers switching to pyrethroid pesticides (less hazardous to mammals and somewhat less disruptive of beneficial insects, but acutely toxic to aquatic organisms); however, partnership activities have also played an important role[45]. The size of this voluntary reduction has generated more research into the almond industry's pesticide use records than any other commodity[46–48]. Stone fruit growers have reduced OP use, in part by switching to 'softer products' as have almond growers, but OP use has not declined as dramatically in this commodity[49]. Stone fruit growers and their organizations have not invested the same scale of effort into partnership activities as have almond growers, but they have to cope with greater cosmetic concerns.

Pear growers reduced OP use faster than any other commodity in the history of California agriculture by substituting pheromone mating disruption products, from over 110,000 pounds in 1998 to 25,000 pounds in 2002. Codling moth resistance to OPs began to appear in the Sacramento region in the early 1990s, and gave a strong impetus to develop the ecological knowledge necessary to make this new pest management strategy effective. Partnerships fostered networks of expert scientific knowledge critical to the successful use of pheromones necessary to support this OP reduction, and to take advantage of biocontrol opportunities in less disrupted farming systems.

Winegrape growers are fortunate to have a crop with few cosmetic concerns, generally lower pest pressure, and many alternatives to OPs to treat their pests, so winegrape partnerships have focused their attention on the entire farming system, more than other commodities. Campos and Zhang[50] and Arounsack et al.[51] have documented reductions of problematic pesticides in three regions where winegrape partnerships have been active.

In sum, agro-environmental partnerships have played a substantial role in reducing pesticide use in these commodities, but they are not the only factor. Weather is the most important factor shaping pest populations and pest management[48], but partnerships have extended critical information about ecologically informed alternatives to OPs and other disruptive pesticides.

Grower Participation in Partnerships

Other researchers have documented the benefits of grower participation in extension, but this research investigated 32 distinct cases. Individual partnerships form the unit of analysis, and this is the first time grower participation across partnerships has been compared in this way. What follows is a presentation of various expressions of grower agency, roles and participation in partnerships. This will be an important background for interpreting the various networking strategies discussed in the final section.

Partnerships structure grower participation, consciously or not. Growers' participation is uneven across partnerships. Some partnerships are organized and substantially directed by growers, while others are operated 'for' growers by extensionists and organizations. Growers have been crucial to the establishment and maintenance of the most active and successful partnerships. The importance of grower participation is not directly proportional to the amount of time they contribute to the management of the partnership, but rather the legitimacy they confer on their activities in the eyes of their peers.

Growers have expressed their leadership by identifying problems, proposing collaborative solutions, initiating partnerships, forming organizations, directing existing organizations to address agro-environmental issues, providing a template of new practices, recruiting growers, and assisting with management team leadership (see Table 2). Only in a few partnerships have growers taken a leadership role in all

Table 2. Growers' roles in establishing partnerships.

Phase	Activity	Number ($n=32$)
Partnership genesis	Identify an environmental problem affecting local growers	26
	Defining the problem and supporting a collaborative solution	20
	Developing or sharing a template of practices for the partnership	11
Recruitment of growers	Leading growers enroll >50% of other grower participants	7
Role on management team	Helping lead the management of partnership activities	8
	Contributing to management team efforts	19

Source: interviews with partnership leaders; $n = 32$ with all partnerships reported.

Table 3. Expressions of participation by leading growers, by numbers of partnerships.

Phase	Activity	Number ($n=32$)
Research	Contributing to formal scientific research	8
	Leading (proposing) the research and development of new practices	15
	Contributing to making the new practices practical	28
	Consenting to others conducting research on property	29
Outreach	Leading outreach activities (organizing field days)	7
	Contributing to outreach (hosting field days, speaking, inviting others)	23
	Serving as a template/mentor grower	14
	Sharing grower knowledge/experience with other growers	30
	Choosing and applying practices from a menu of options, and assuming the risks (versus practices chosen by others)	24
Evaluation	Contributing to a formal evaluation forum (committee, focus group, survey, interviews)	21

Source: interviews with partnership leaders; all partnerships reported.

of these activities. They generally do not contribute to the day-to-day management of the partnership itself, but their participation ensures that scientists' research will be of practical use, and persuades other growers of its viability. Other growers attend to the authority of their peers who have invested their time and taken economic risks on agroecological practices. Growers identified production problems and sought out collaborative solutions in 11 of the partnerships.

Most partnership leaders ascribe significant importance to the contribution of 'leading growers' to the overall success of the project, even if only one or two growers play a leadership role. The distinction between leading growers and enrolled growers is crucial to understanding different expressions of grower participation. The term 'leading growers' distinguishes their role from others because it indicates they have researched integrated farming systems and actively engage others in discussions of these practices. Leading growers have a vision of agriculture that does a better job of stewarding environmental resources, and they translate that into a vital model. They recognize that they are more likely to attract the attention of researchers if they are organized into a group, and are independently motivated to try new practices (see Table 3). For example, in the Lodi winegrape partnership, several leading growers persuaded their neighbors to accept a mandatory per-ton 'self-tax' on their winegrapes to fund specialized, local research and education projects, and marketing efforts[52]. The importance of grower participation in establishing and orienting partnership activities cannot be overstated. In 11 partnerships, leading growers were designated template growers, meaning they have a farming system for other growers to emulate, or mentor growers, indicating they will help less skilled growers learn about new techniques. Glenn Anderson of the almond BIOS partners exemplifies a template grower.

The term 'enrolled growers' indicates that their participation in the partnership was solicited by someone else, whether a leading grower or an extensionist. Enrolled growers manifest less initiative than leading growers, and play a less influential role in partnerships, because they are recruited to a partnership already designed by others. Thirty partnerships formally enrolled as growers, and their participation is reported in Table 4. Enrolled growers are expected to dedicate a field or block for experimenting with a new practice, learn more about pest or fertility monitoring, and share this information with other growers and extension actors in a structured way. Enrolled grower participation is necessarily less active than that of leading growers.

Some partnerships explicitly try to facilitate growers re-thinking on their farm management decision-making process. Many of these partnership strategies, such as having the grower select from a menu of options and

Table 4. Expressions of enrolled grower participation, by numbers of partnerships.

Partnerships expected enrolled growers to	Number ($n=30$)
Enroll by	
Engaging in a structured research and social learning process	30
Dedicating a block for alternative practices for >1 year	29
Dedicating comparison blocks	25
Learn by:	
Participating in agroecological pest, soil, water and fertility monitoring	29
Sharing with other growers in a structured way	26
Selecting from a menu of agroecological pest, soil, or irrigation management techniques	18
Experiment with:	
Agroecological pest management techniques	29
Agroecological soil and irrigation management techniques (e.g., cover cropping, conservation tillage, irrigation monitoring)	20
Integrate farming systems by:	
Evaluating the impact of system components (e.g., the impact of fertility and water management on pest pressure)	22
Creating farming system management plans (with extensionists)	15

Source: interviews with leaders of partnerships that formally enrolled growers ($n = 30$).

collaboratively developing a farm management plan, were originally promoted by BIOS. The manuals emerging from partnerships, described above, are an attempt to formally expand the range of menu options, beyond that of conventional wisdom. Engaging growers with a menu of options demands additional effort from partnership leaders, but it facilitates more active learning on the part of growers and does appear to result in better farming decisions over a time.

Many participating growers report they now make decisions on a multiple criteria basis. Many leading growers in partnerships insist that agroecologically based farming can cost the same or less, but only if the entire farming system is evaluated. For all its technical sophistication, California agriculture has tremendous variability in its practices, suggesting that growers have greater flexibility in their operations than many realize. Facilitating the development of farm management plans can help growers recognize the value of monitoring data and incorporate it into adaptive decision making. This is fundamentally different than technology transfer.

Engaging Networks

The highly specialized, narrowly defined roles of growers, consultants and scientists in California agriculture are incompatible with a facile assumption about participation from the 'Farmer First' development literature[1]. Core principles of power dynamics and social learning still apply, but the highly specialized division of labor here is profoundly different than in the developing world. California agriculture is among the most technologically advanced in the world, and consultants, scientists, growers and farm workers have narrowly conceived roles. Successful partnerships have provided growers new and multiple perspectives on farm management, and helped them develop a more complete framework for understanding the ecological dynamics of their farming system.

California growers make decisions in dialogue with others. In addition to university-generated research, they draw on the knowledge expertise of fellow growers, private scientists and growers' organizations. Extending agroecology requires engaging these social influences on grower behavior. This section describes how partnerships facilitate enhanced knowledge exchange between growers, private consultants and agricultural organizations.

California's hyper-specialized farming systems plus its relatively strict pesticide regulations have given rise to the Pest Control Advisor (PCA), a state licensed, privatized extensionist combining specialized university-generated expertise with practical, field-based experiential knowledge. More than anyone else, they are able to observe regional trends in pest pressure and propose a menu of tactics that can control them, and they often have the most influence on decisions to apply pesticides. Many large growers rely heavily on the counsel of PCAs to make pest management decisions, and some draw on the expertise of two or even three.

Over 80% of all PCAs work for agrochemical sales companies, and receive from them base pay plus a commission on all materials they sell. Critics refer to these as 'chemical company PCAs,' but they prefer to be known as 'affiliated PCAs.' Affiliated PCAs provide a seamless package of expert advice plus pesticide sales, delivery and application, depending on the needs of the grower, but the 'value' of the recommendation is folded into the price of the agrochemicals. A small minority of PCAs are independent consultants who contract their services for monitoring and consulting directly with the grower. Independent PCAs are paid on a per acre basis. Many report earning less money as independent PCAs, but having superior job satisfaction.

Twenty-seven partnership leaders reported enrolling a total of 84 PCAs as formal partners, 38 of them independent PCAs. This is a disproportionately high number of independent PCAs, and they have played important leadership roles in some partnerships, in terms of both the applied science, and overall group leadership. Twenty-one partnership management teams included one or two PCAs, enhancing the credibility of partnership activities among other PCAs. Both kinds of PCAs report they participate in partnerships because it offers them the opportunity to

Table 5. Social learning and relationships between leading and enrolled growers.

Social learning type	Relationships between leading and enrolled growers	Social learning occurs?	Number ($n=32$)	Growers came into this role by:	Comments
Incubation	Leading growers all learn together as a group; other growers only learn later	Yes, within the group	5	Leading growers volunteered for it	Often used for initial field-based research
Entrepreneurial learning	Leading growers develop alternative practices and promote them through an organization for other growers, formally enrolled or not	Yes, within group and publicly	3	Leading growers volunteer for it, and promote participation by others	Only found in winegrape partnerships
BIOS model	Leading growers provide template, and enrolled growers adapt; social learning occurs	Yes, within group and publicly	15	Extension actors negotiate roles with both kinds of growers	Also known as the BIOS-inspired BIFS model
PMA model	Enrolled growers receive practices from extension agent; others learn by observation	Yes, publicly	7	Invitation from extensionist	Inserting alternative practices into conventional extension model
Reduced Risk Research	Only enrolled growers; no evidence of social learning by growers	No	2	Invitation from extensionist	Consent to pesticide trials

sharpen their skills, develop professionally and 'improve the system' of pest management.

Partnership leaders report mixed success working with PCAs. They praise PCAs who actively participate for helping to make partnership practices economically feasible, but they report most affiliated PCAs express skepticism and passively resist pesticide reduction goals. PCAs apparently contributed less than growers, but their participation was nevertheless essential to partnerships' honing agroecological pest management techniques.

Many growers and their consultants do perceive partnership practices to carry increased risk without offering a sufficient return. Some partnerships try to re-configure risk perception by introducing a broader array of knowledge about risks. Additional research into the role and re-configuration of risk agroecological practices would help agro-environmental partnership participants understand the dynamics of partnership activities.

Networking Growers Through Social Learning

Differences in farming systems and social relations across commodities have given rise to multiple forms of social learning. Table 5 reports five major types of social learning, shaped by relationships between leading growers, enrolled growers and extensionists. In general, the first three types evince more active discovery learning and dynamic knowledge sharing between actors.

In the Incubation type, growers learn together, and minimize distinctions between those who initiate the partnership and those who join it later. The emphasis here is on formal and informal learning through collaborative research by scientists, PCAs and growers. Field days may be held, but there is little emphasis on outreach. Non-enrolled growers learn about partnership practices at a later time. Growers initiate these partnerships for themselves and each other. This model has been used more for initial field-scale agroecological research, the discovery stage described above.

The second type of configuration, Entrepreneurial Learning, consists of leading growers forming a co-learning relationship like the first type, but in addition they take the practices they develop and promote them to other growers through an organization. Social learning here takes place among leading growers, but they realized the benefits that could be captured by helping neighboring growers to improve their practices, and they wanted to formalize this educational process by creating an organzation. An initial emphasis on facilitating learning by leading growers subsequently gives way to broader outreach in the region. All three examples of this model occur in the winegrape industry. Local winegrape partnerships have deployed this model to focus more attention on their identified research needs, draw on the resources of existing local organizations to aide marketing, and to help 'bring along' other growers to enhance the reputation of regional growers as environmentally responsible (this is a phrase common only to the winegrape partnerships).

The most common configuration among partnerships is the BIOS model, in large part because the BIFS program tried to institutionalize this approach. In this, extension

actors identify one or two template growers and propose their farming systems as examples for other growers. In some cases, the extensionist has provided expert knowledge and guidance to the leading grower during previous years, and a partnership provides a structure for further promoting these practices. This configuration facilitates variable combinations of research and outreach, and they often are conducted simultaneously. Clear results are extended broadly, and scientific uncertainties are communicated as such. In this configuration, outreach is targeted to enrolled growers, who receive concerted attention and resources in the form of farm visits, access to new products and cost sharing for resource conservation tools like cover crop seeds. Other growers are invited to field days and encouraged to learn about agroecological practices at field days and put them to use on their own farm. In almost all of these cases, enrolled growers selected from a menu of practices, and were expected to share the results of their experimentation. Social learning activities are focused on the extension actors and the leading and enrolled growers, and to a lesser extent on other growers and PCAs.

In the PMA model, UCCE extensionists test a suite of agroecologically informed practices in field-scale conditions on the orchards and farms of cooperating growers. Growers may make practical suggestions as to making the program work, and their observation and experience may be important contributions to the partnership, but their fundamental role is hosting the research and demonstration site. Scientists and extensionists run the management team and evaluate the results of experiments. Growers do not propose practices, nor do they select them from a menu, and they do not make substantive contributions to the management team. This model does not readily facilitate initiative or leadership from growers, and generally has fewer leading growers than other models. The organizers of partnerships with this configuration did not speak of intentionally excluding growers, nor did they report them making any important contribution.

Two partnerships were configured so as to have virtually no participation from the growers in research or outreach, and are thus labeled Reduced Risk Research. In practice, these partnerships worked closely with PCAs, and the operational definition of grower participation consisted of consenting to research being done on their fields. Neither of these partnerships exhibited social learning, and are included here for contrast.

Conclusion

To successfully extend agroecology, growers and extensionists must be able to create networks of social learning. They create these networks to apply agroecological principles to specific farming systems. Four of the five types of networks detailed above manifest the kind of knowledge exchange necessary for agroecological learning. Participation in these networks necessarily varies by the character of a crop's farming system, progress in developing agroecological knowledge and the social relations among a commodity's growers.

Agroecological principles have demonstrable application to the monocultural farming systems in California. The agro-environmental partnerships deploying them have made a substantial contribution to the reduction of hazardous agrochemicals in almonds, pears, stone fruit and winegrapes.

Extending agroecological knowledge requires an alternative to the transfer of technology pedagogy. Agroecology requires more dynamic interactions to support learning by growers, extensionists and scientists about the ecological relationships between technological and biological components of farming systems. Knowledge exchange between growers can often be equally important as knowledge exchange between extensionists and growers.

Substantial progress has been made in researching agroecological principles. Extending agroecology requires a pedagogy that engages network growers and their consultants in social learning.

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Intended and actual behavior of organic farmers in Austria after a five-year commitment period

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Abstract

Organic farmers throughout Austria were asked in 1999 if, once the first agri-environmental program (ÖPUL) ends, they intended to commit themselves to a further five-year period of organic farming. The study presented here addresses those farmers who expressed in the survey the intention to end their participation in organic farming under ÖPUL, or who were undecided at that time. The aim was to compare and analyze the intended behavior with actual behavior. The research was based on material from, and analyses of, the 1999 survey and the survey conducted in 2002. Additional information regarding the reasons for abandoning (or continuing) organic farming and the decision-making process itself was collected through a series of telephone interviews in 2004. The comparison revealed a connection between actual behavior and the intentions expressed in the 1999 survey. However, there were no clear differences in terms of the reasons given in 1999 for potentially discontinuing with organic farming between those farms that remained organic and those that reverted to conventional farming methods. There were differences between those reasons given in the 1999 survey for potentially leaving organic agriculture and the reasons that determined the actual decision, as cited in telephone interviews in 2004. In the 1999 survey, economic issues were the main reasons for potentially ceasing to farm organically. When it came to the actual decision, problems concerning organic guidelines and inspections were more prominent. The environmental attitudes and the social embedding of the farmers within organic agriculture played a decisive role on those enterprises that chose to continue farming organically. The analysis indicates that the presence of a successor is also a stabilizing factor for organic farming.

Key words: organic farming, intended and actual behavior, environmental attitudes, survey and interview, organic farmers, ÖPUL

Introduction

Organic farming in Austria expanded slowly in the 1970s and 1980s, but the 1990s saw the number of organic farms increase rapidly to over 20,000, representing about 10% of all agricultural enterprises[1]. Both organic farming support measures and an expansion in relevant marketing initiatives contributed to this upturn in numbers[2–4].

An agro-environmental program (ÖPUL—an acronym for the 'Austrian Support Program for an Environmentally Compatible, Extensive Agriculture that Protects the Natural Ecosystem') was introduced by the Austrian government in 1995, and used area payments to support organic farming methods and other practices of relevance to the environment[5,6]. Farmers who participated in any of the ÖPUL measures committed themselves to the requirements for a five-year period. The first such period expired at the end of 1999 (ÖPUL 1995). By the end of 1998, it was already apparent that not all of those farms participating in ÖPUL's organic farming measure would do so again in the next period. Given this likely development, in 1999 the opportunity was taken to conduct a written survey of organic farmers with regard to their intended behavior in this context. A questionnaire was sent to 1500 randomly chosen organic farmers (out of a total of 18,960 organic farmers all over Austria), and 600 responses were returned on the issue of further participation in the relevant organic farming measure within ÖPUL. At that time, almost

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two-thirds intended to continue their participation, around 13% wanted to abandon organic farming, and some 23% were still undecided. Once the stipulated five-year period expired, the obvious question to ask was just what did these farmers actually decide regarding their participation in the successor program?

The 1999 survey was anonymous. Nevertheless, respondents were invited to voluntarily give their contact details should they be willing to be contacted again for more information. One hundred and twenty-six (around 20% of respondents) did so, thus providing an opportunity to identify their actual behavior and to compare this to the intentions they had expressed in the original survey.

The study presented here deals with those farmers who volunteered their contact details in 1999, and who indicated at the time that they would not participate in the organic farming measure within ÖPUL 2000, or who were still undecided. The research is based on the 1999 written survey and its subsequent analysis[1] and a second written survey conducted in 2002[7]. Additional telephone interviews were conducted in 2004 to collect further information regarding the farmers' decision-making processes and reasons for not continuing with organic agriculture. The aim of the research is a comparative analysis of the intended and actual behavior of the farmers. The expressed intentions with regard to continued participation in the ÖPUL organic farming measure are contrasted with the farmers' actual behavior in this context, and the reasons for discontinuing participation (or for remaining in the program) are explained. In addition, the possible explanations for any deviations between intended and actual behavior are explored. Finally, the role of environmental attitudes, the family tradition and the embedding in social networks in the farmers' decision-making is also examined.

The decision-making process in the context of continuing or abandoning organic farming after a certain commitment period has not been explored comprehensively. Since the material described above was available in Austria, the opportunity was taken to initiate a study on the subject of decision-making toward or against organic farming.

First, it seems necessary to give some brief information about ÖPUL 1995. Then important changes in the formal requirements associated with participation in ÖPUL 2000 and especially concerning organic farms are presented. In order to understand the relevance of this study, the changes in the number of farms quitting organic farming in the years 2000, 2001 and 2002 are presented. Since this study is based on the results of the 1999 and 2002 surveys to a great extent, information is given about the concepts of these surveys. The results of these surveys are presented in summary form, whereas emphasis is given to the various research categories of farmers emerging from the answers of the farmers. Finally, the categories of farmers relevant to the telephone interviews which were conducted for this paper in 2004 are discussed.

Background information

Relevant ÖPUL characteristics

In 1995, the first year of establishing ÖPUL 95, about 175,000 farms, around 78% of all farms in Austria, committed themselves to the program; 15,900 farmers decided for the measure organic farming. By 1999, the number of participants in this measure increased to 18,960. The organic farms cultivated, in 1999, about 270,000 ha farmland, 60,000 ha of which was arable land. The average size of the organic farms was 14.4 ha (without Alpine pastures and forests). A maximum of two animal units are allowed per hectare. About 86% of the organic farms in 1999 kept animals, 69% of them dairy cows. The milk quota of the organic dairy farms summed up to around 400,000 metric tons, about one-third of the organic milk could be sold with a premium in 1999. Only a low proportion of the beef produced in Austria was sold as organic[4,8].

Agrarmarkt Austria (AMA) administers the agro-environment program on behalf of the Ministry of Agriculture, as all other direct payments to farmers within the Common Agricultural Policy. The technical inspection service of AMA controls the proper application of the ÖPUL measures chosen by the farmers. At least 5% of farmers participating in the ÖPUL measure organic farming will be inspected each year within these controls.

All organic farmers must operate according to the Regulation (EEC) 2092/91 and the Austrian Codex Alimentarius. Since 1991, there have been major amendments of this regulation; 1804/99 covers production, labeling and inspection of the relevant livestock species. Most organic farms are affiliated to organic farm associations. These members must further fulfill the regulations reflecting the specific philosophy of the association. To ensure the EU standards and regulations, unannounced inspections are conducted at least once each year by one of the certification bodies. For a certificate, a complete and plausible inspection report and the fulfillment of all legal requirements are necessary. A valid contract with a certifying body is required to be eligible for the direct payments for organic farming and to be allowed to label products as organic. The specific regulations of the organic farm associations are controlled by the certification bodies too. The farmers have to pay for the inspections; the cost depends on the farm size; for up to 10 hectares, the farmers get a subsidy for the cost of control[9,10].

The area payments for supporting organic farming amounted in 1999 to €327 per hectare arable land and €218 per hectare meadow and pasture land (except for Alpine pastures; for those, the number of animals grazing is relevant for the payments). To compare: farmers who committed themselves to the ÖPUL measure renunciation of yield-increasing inputs received per hectare €218 for arable land and €145 for meadows and pastures. Thus the additional payments per hectare for organic farming compared to this alternative are €109 and €73 respectively (all figures rounded)[5].

Table 1. Comparison of the characteristics of survey farms in 1999 with those of all organic farms in 1999.

Characteristic	All Austrian organic farms (18,960)		Surveyed organic farms in 1999 (n = 600)		
				Confidence interval	
	Number of farms	Mean[1]	Mean[1]	Lower critical value	Upper critical value
Agricultural land (ha)	18,960	14.4	16.0	14.9	17.0
Grassland (ha)	18,576	11.4	12.0	11.4	12.7
Arable land (ha)	7,527	8.0	9.7	7.9	11.5
Cattle (number)	16,242	20.5	21.3	20.0	22.5
Milk cows (number)	11,242	8.7	9.3	8.6	9.9
Pigs (number)	8,315	4.6	3.3	2.6	4.1
Chickens (number)	9,355	31.8	22.2	14.3	30.1
Sheep (number)	3,405	27.6	26.8	19.2	34.3

[1] Mean refers to the number of farms with grassland, arable land and particular species of animals.
Source: Invekos-Data 1999; 1999 survey.

The introduction of ÖPUL 2000 was delayed by a year. This meant that farmers could operate for an additional year under the conditions agreed within ÖPUL 1995. The length of time between the first survey in 1999 and the final deadline for making a decision on renewed ÖPUL participation was therefore extended for those organic farms who chose to add on this extra year. Also, some farms did not initially commit to organic farming in 1995, but did so at a later date (the provisions of the program allowed participating farms to later switch to the more ecologically valuable organic farming measure). The five-year period of commitment then began with the date of this change, so, for example, an enterprise that chose to operate organically from the beginning of 1997 could not then abandon organic farming until the end of 2001, at the earliest. Anyone abandoning organic farming methods before the end of the five-year commitment was obliged to pay back the relevant premia. If the farmer stopped working the farm, then there was no requirement to pay back the premia, provided someone else continued to farm the land in question organically.

The premia offered for farming grassland and specialist crops organically were increased in ÖPUL 2000; the support for organic enterprises with grassland and/or specialist crops improved relative to other measures within ÖPUL. The formalities of applying for premia were also simplified for all ÖPUL measures[11].

Changes in the number of organic farms

At the end of 1999, around 1500 enterprises (8%) ceased participating in the organic farming measure. Some 1250 enterprises (7%) left at the end of 2000, and about 600 (3%) at the end of 2001. All of these enterprises switched to other measures within ÖPUL. During this time-frame, some enterprises decided to convert to organic farming for the first time, so the total number of organic farms within ÖPUL fell from 18,960 in 1999 to around 16,300 in 2001[12]; a decline of about 14%. The total number of organic farms in Austria in any given year is between 5 and 7% higher, since not all organic farms participate in ÖPUL's organic farming measure.

1999 survey

Out of a total of 18,960 organic farms in Austria, 1500 were randomly selected. A questionnaire containing questions about: (i) characteristics of the farms and farmers; (ii) plans about future participation in organic farming and other ÖPUL measures; and (iii) possible reasons for abandoning organic farming was sent to these farmers in 1999. The respondents cultivated statistically significantly more agricultural land per farm and kept fewer chickens and pigs per farm than the average of all organic farms also statistically significant. The other six characteristics listed in Table 1 were not statistically different between the farm sample and all organic farms in 1999.

The responses of those 126 organic farmers who provided their contact details when returning the questionnaire in 1999 deviate only slightly from those of all respondents in terms of their distribution between the three relevant categories of *intending to continue farming organically under ÖPUL, intending to end their participation in this ÖPUL measure* and *undecided* (Table 2). As such, these 126 enterprises can be used to draw out conclusions with regard to the actual behavior at the end of the period of commitment in comparison with the intended behavior.

Of those 78 farmers who planned to continue organic farming in the successor ÖPUL, 76 actually did so, and two did not.

2002 survey

In 1999, 48 of the farmers who provided contact details either intended to abandon organic farming or were as yet undecided (Table 2). A questionnaire was sent to these farmers in 2002. The questionnaire contained: (i) the

Table 2. Comparison of the answers given in 1999 by all respondents with those given by respondents who also provided contact details.

Intended behavior once the period of commitment ends	All respondents		Respondents giving contact info.	
	Number	Percent	Number	Percent
Continue participation	388	64.7	78	61.9
End participation	76	12.7	18	14.3
Undecided	136	22.7	30	23.8
Total	600	100.0	126	100.0

Source: Analysis of the 1999 survey.

Table 3. Intended and actual behavior after the end of the period of commitment.

1999 survey Intended behavior		2002 survey Actual behavior	
Response	Number of enterprises	Remained organic	Reverted to conventional farming
Leave organic farming	13	5	8
Undecided	25	20	5
Total	38	25	13

Source: Analysis of the 1999 and 2002 surveys.

question of whether the farmers were at that time still participating in the ÖPUL measure organic farming; (ii) if yes, the reasons for the continued organic farming were assessed through a multiple choice question; and (iii) in case of having abandoned organic farming in the meantime, the reasons for this decision were also assessed through a multiple choice question; and finally (iv) the questionnaire also asked the responders to give some suggestions for improving the conditions of organic farming. Of the 48 farmers, 38 returned valid questionnaires.

Although this subset of farmers who provided contact details was not a selected random sample, the means of the farm characteristics were similar to the average of the respondents of the 1999 survey. On average, they cultivated 16.0 ha agricultural land, 11.7 ha grassland and 10.1 ha arable land (farms with grassland and arable land respectively).

Based on the results of this survey, 8 of 13 farmers who intended to cease their participation in the organic farming measure actually did so. Of the 25 who had been undecided, 20 continued to farm organically under ÖPUL (Table 3).

2004 survey

An interest in that final decision for or against continued organic farming led to an additional telephone survey in 2004 where those 13 farmers (Table 3, last column) who did abandon organic farming were interviewed in detail about this decision. Telephone interviews were also carried out with a second group of farmers, namely those five who had indicated in 1999 that they would abandon organic farming, but who instead continued to farm organically under the new ÖPUL regime.

Research issues

The discrepancy between the intended and actual behavior of some farmers raised the following issues:

1. Were the reasons given in 1999 for the intended exit from organic farming an adequate indicator of a farmer's actual behavior when the final decision was made?
2. What were the actual reasons for abandoning organic farming?
3. Did the actual reasons for abandoning organic farming match those given in 1999?
4. What was the decision-making process that led to abandonment and what is the attitude to converting back to organic farming?
5. What explanations are there for the behavior of those farmers who continued to farm organically despite declaring in 1999 their intent to return to conventional agriculture?
6. What insights into the role of environmental attitudes in the decision to remain in organic farming can be gained from the surveys?

Approach

The answers to the above questions were derived from pre-existing data and analyses from the 1999 and 2002 surveys[1,7], new analysis of the 2002 survey, and the telephone survey conducted in 2004. Since the exploration of each of the research issues required very different methods, it seems sensible to describe the relevant methods used when discussing each particular issue, rather than collate them all in a standalone section. As such, the rest of this paper follows the order of questions noted above.

Results

Research issue 1

Were the reasons given in 1999 for the intended exit from organic farming an adequate indicator of a farmer's actual behavior when the final decision was made?

Sixteen possible reasons for abandoning organic farming were listed as statements in the 1999 questionnaire.

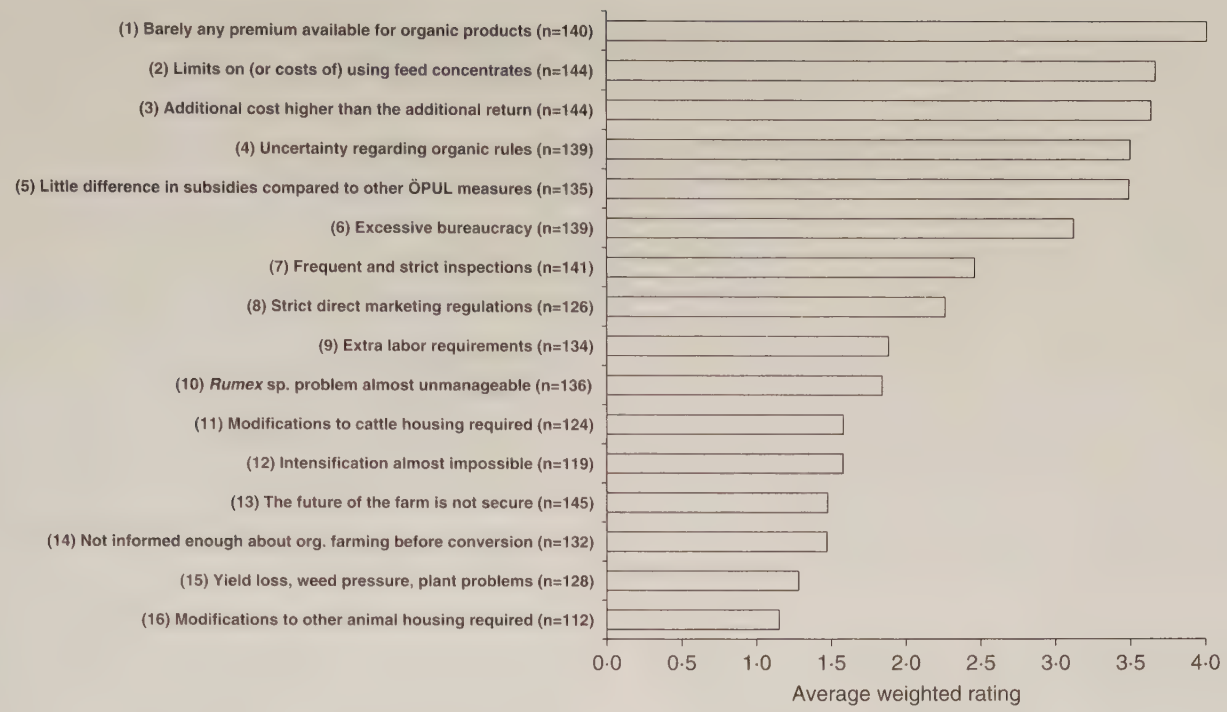
(1) Barely any premium available for organic products (n=140)
(2) Limits on (or costs of) using feed concentrates (n=144)
(3) Additional cost higher than the additional return (n=144)
(4) Uncertainty regarding organic rules (n=139)
(5) Little difference in subsidies compared to other ÖPUL measures (n=135)
(6) Excessive bureaucracy (n=139)
(7) Frequent and strict inspections (n=141)
(8) Strict direct marketing regulations (n=126)
(9) Extra labor requirements (n=134)
(10) Rumex sp. problem almost unmanageable (n=136)
(11) Modifications to cattle housing required (n=124)
(12) Intensification almost impossible (n=119)
(13) The future of the farm is not secure (n=145)
(14) Not informed enough about org. farming before conversion (n=132)
(15) Yield loss, weed pressure, plant problems (n=128)
(16) Modifications to other animal housing required (n=112)
0·0 0·5 1·0 1·5 2·0 2·5 3·0 3·5 4·0
Average weighted rating

Figure 1. Average weighted rating for each potential reason for abandoning organic farming. Weighting: very relevant = 5, relevant = 3, of some relevance = 1, irrelevant = 0. Source: 1999 survey, farms planning to abandon organic farming or as yet undecided.

Farmers intending to revert to non-organic farming methods or who were as yet undecided were invited to declare the relevance of each reason to their intentions on a four-point Likert-type scale. The ratings available were 'very relevant', 'relevant', 'of some relevance' and 'irrelevant'. These were awarded the numeric weightings 5, 3, 1 and 0 respectively, and an average rating for each reason was calculated from the responses (Fig. 1). These averages were taken as indicative of the importance of each potential reason to a decision to abandon organic farming. Because of the fact that not every farmer, who planned to end participation or was undecided, rated every reason listed, the statements received between 112 and 145 ratings.

Statistical analysis showed that the reasons for abandoning organic farming are not independent of each other. Using factor analysis, four independent influential factors were drawn out of the total set of reasons and categorized as *organic regulations*, *value added*, *management* and *housing investment*[1]. *The value added* factor summarizes those reasons labeled as 1, 2, 3 and 5 in Figure 1; *organic regulations* covers reasons 4, 6, 7, 8 and 14; *management* covers reasons 9, 12, 13 and 15; *housing investment* covers reasons 11 and 16. The reason '*Rumex* sp. problem almost unmanageable' could not be allocated to any of the four factors. Figure 1 shows that the reasons given the highest average ratings relate to the two factors *value added* and *organic regulations*.

In a next step, an average rating across all the possible reasons was calculated for each farm; reasons given no rating were not included in the calculation. The aim was to address the question of whether the reasons given in 1999 for the intended or possible abandonment of organic farming were indicative of the subsequent actual behavior of the farmers. This average rating says nothing about the total number of reasons rated, yet this total could also be of relevance to the farmer's actual behavior. Therefore, the following approach was adapted from the four-field matrix of the Boston Consulting Group[13]. In Figure 2, the abscissa represents the number of reasons rated by a particular farmer, given as a proportion of the total number of reasons available for rating. The ordinate is the average value of all ratings given by that farmer. The maximum value for the ordinate is 5 (very relevant). For a farm to reach 100% on the axis of abscissas, the farmer must have rated every potential reason listed in the questionnaire. Figure 2 shows the results for 28 farms (10 of the 38 farmers who in 1999 considered leaving organic agriculture or who were undecided gave no reasons).

Figure 2 does not suggest any clear differences in ratings between those farms that eventually continued to farm organically and those that switched to other measures within ÖPUL. This would imply that the ratings given in the 1999 survey are not an indicator of the eventual choice of farming method within ÖPUL 2000. This fact was the catalyst for undertaking the telephone survey of those enterprises in the upper right quadrant of Figure 2 who still continued to farm organically, since their decision seemed to contradict the data available. This topic is examined in research issues 5 and 6.

Research issue 2

What were the actual reasons for abandoning organic farming?

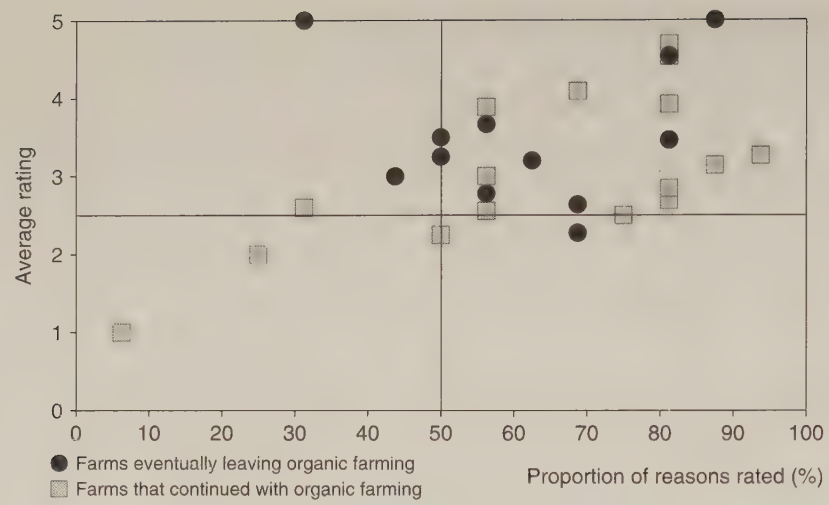

Figure 2. Average ratings given in 1999 to possible reasons for intending to abandon organic farming, differentiated according to the subsequent actual decision taken regarding farming methods. Source: based on the 1999 and 2002 surveys.

Telephone interviews were carried out with 13 farmers in 2004 to establish the actual reasons for their abandoning organic farming. Each reason given in the interviews was allocated to one of the four factors—*organic regulations*, *value added*, *management* and *housing investment*—in order to properly answer the question in hand. Selected structural characteristics of possible relevance to the decision to leave organic farming were identified to describe the farms.

In 9 of the 13 farms, the real reasons for abandoning organic farming related to only one of the four factors: the factor *organic regulations* in four cases, the factor *management* in three cases, and the factor *value added* in two cases. The remaining four farmers cited reasons applicable to two or more factors: the factors *organic regulations* and *value added* in one case, the factors *organic regulations*, *value added* and *management* in two cases, and one farmer gave reasons covering all four factors. The reason '*Rumex* sp. problem almost unmanageable' was not mentioned by any of the 13 farmers as relevant to their actual decision to cease using organic farming methods.

The explanations given by the farmers for their eventual decisions were not, therefore, uniform. It is interesting, however, to explore whether the division of farms according to their reasons for returning to conventional agriculture is matched by equivalent structural differences. Table 4 groups the farms based on factor analysis of the reasons they gave for their opt-out decision and then lists selected average per-farm structural characteristics for each group.

The four farmers whose reasons for opting out of organic farming could be summarized under *organic regulations* farm an average of just over 7 hectares on a part-time basis. The three farmers who cited *management*-related reasons farm an average of just under 7 hectares, and two of them run full-time dairy enterprises. *Value-added* reasons were an issue for those two individuals farming an average of 16 hectares full-time. The reasons cited by those full-time farmers with an average of 25 hectares were more diverse than those cited by farmers with less agricultural land.

The reasons given for leaving organic farming appear to be closely related to particular structural characteristics of the farms concerned. Farmers with small enterprises opt-out due to reasons associated with the factors *organic regulations* and *management*. *Value-added* concerns or a combination of factors were decisive in causing larger farms to take a similar step.

Research issue 3

Did the actual reasons for abandoning organic farming match those given in 1999?

Table 4. Reasons for abandoning organic farming methods based on factor analysis, and selected farm structural characteristics (average per farm).

		Agricultural land (ha)		Number of farms with		Farming status	
Reason(s) given	**Number of farms**	**Total**	**Of which grassland**	**Dairy cows**	**Other livestock**	**Full-time**	**Part-time**
Organic regulations	4	7.3	7.3	1	3	0	4
Management	3	6.9	5.6	2	1	2	1
Value added	2	15.6	15.6	1	1	2	0
Multiple factors	4	25.1	21.7	3	1	4	0

Source: 1999 and 2004 surveys.

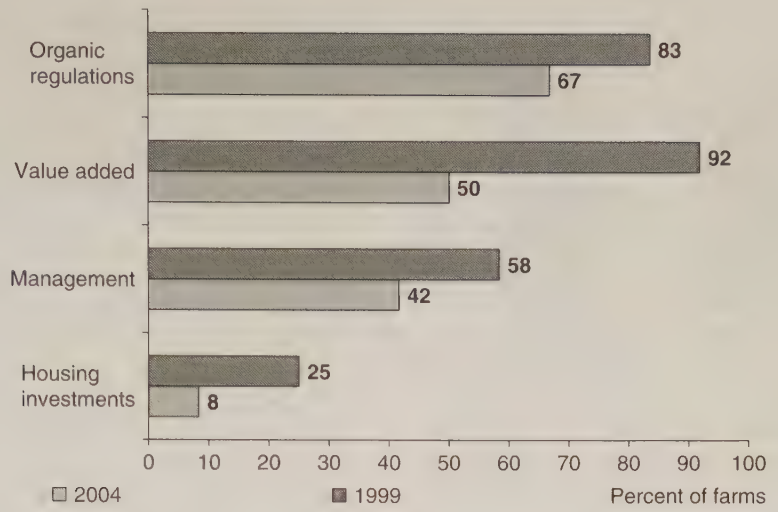

Figure 3. A comparison of *ex ante* and *ex post* reasons for abandoning organic farming methods. Source: 1999 and 2004 surveys, 12 farms.

To address this issue, a comparison was made at the factor level (*organic regulations*, *value added*, *management* and *housing investments*) between the reasons given in the 1999 survey by each farmer and those given in the 2004 telephone interviews (Fig. 3). Regarding the former, only those reasons that had been rated 'very relevant' or 'relevant' were used for the comparison. Where the reasons cited on the telephone differed from those given in 1999, the interviewee was asked to explain why. Since one of the telephone interviewees did not rate reasons in the 1999 survey, the comparison covered 12 farms.

The comparison shows that fewer factors were responsible for the actual decision to leave organic farming. In particular, the *value added* factor was mentioned far less often. In 1999, 11 of the 12 farmers cited reasons related to the factor *value added* as relevant or very relevant, while only half did so in 2004. Reasons related to the other factors were also cited less often in 2004 than in 1999, but the absolute drops in numbers were lower.

The *ex ante* reasons given in 1999 and the actual reasons cited in the 2004 telephone survey are compared in the following results at the factor level.

On two farms, the two sets of reasons for leaving organic farming were identical. These concerned the factors *organic regulations* and *value added* on one of those farms, and all four factors on the other.

On a further eight farms, the two sets of reasons were broadly similar. All of the actual reasons cited for the eventual decision had also been cited in 1999. On six farms, some of the reasons given in 1999 were no longer relevant by the time of the actual decision, because of a change in circumstances or perspective. One farmer had in the meantime modified his livestock housing conform to requirements. On two farms, the economics of the situation were a good reason for opting out of organic farming in 1999, but this was no longer the case by the time the actual decision was made, as these quotes demonstrate: '*I would have accepted the financial disadvantages, were it not for the permanent inspections* ...'; '... *the economics of it all are a minor issue for me* ...'. The remaining three farmers could no longer explain why they mentioned more reasons in 1999 than were relevant come decision time.

In two cases, fewer factors were cited in the earlier survey regarding intended behavior than were cited during the telephone survey with respect to the actual final decision. One of the farmers had a problem with the organic regulations just before the decision on opting out had to be made and—from his perspective—received too little support from his organic association: '... *with more support from the association I might have thought again about leaving organic farming* ...'. The other farmer could not explain why he had given fewer reasons in 1999 than he subsequently cited as important for the decision in 2004.

No adequate evaluation of the degree of correspondence between the reasons given in 1999 and those given in 2004 was possible on 2 of the 12 farms, because significant changes in the post-1999 lives of the farmers had caused them to abandon organic farming. The high age of the farmer on one enterprise meant that the cattle could no longer be allowed out on range, which in turn meant the legal requirements for organic animal production could no longer be met. In the other case, poor health led to the farmer renting out the land to his children, who did not retain the livestock and chose to farm conventionally.

In summary, there were fewer reasons actually responsible for the eventual decision to leave organic farming than originally given in the 1999 survey. Many reasons were no longer relevant. Those reasons associated with the *value added* factor were no longer in the majority when it came to the final decision. The reasons for opting out cited most frequently by farmers in 2004 were those associated with the *organic regulations* factor. Strict inspections (or inspections perceived to be too frequent) played some role in the final decision in 60% of cases. For 30% of the farmers, inspection issues were even the main reason for leaving organic agriculture.

Research issue 4

What was the decision-making process that led to abandonment and what is the attitude to converting back to organic farming?

In the telephone interviews conducted in 2004, those 13 farmers who had reverted to conventional farming were also asked about the decision-making process itself. The interviewer also explored their attitudes toward a possible return to organic farming methods.

Nine of the 13 farmers reached their decision quickly and easily. The following statement is characteristic for this group: '*... I'd been waiting ever since 1999 for the opportunity to stop farming organically.*' The decision-making process was a longer one for four of the farmers, i.e. they took longer to weigh up the advantages and disadvantages of staying in organic farming. One of the farmers had already converted his cattle housing to one suited to organic animal husbandry before reaching a final decision. A change in inspector delayed the decision for another farmer. The two other farmers gave no clear reason for the longer decision-making process.

Three of the 13 farmers would consider a return to organic farming given the right conditions. The prerequisite for one farmer was, '*... that there aren't so many extra inspections and farm records required.*' Another farmer wanted more price security and formal guidelines and requirements to cover reconversion to organic methods. The third farmer could imagine returning to organic farming, but not without first getting detailed information on the current requirements associated with this form of agriculture.

In summary, for most of the farmers the decision to abandon organic farming was an easy one. The statements made by the farmers also reveal that with hindsight they regard the decision they took to have been the correct one. As a consequence, the possibility of returning to organic farming methods is only something a small minority would consider.

Research issue 5

What explanations are there for the behavior of those farmers who continued to farm organically despite declaring in 1999 their intent to return to conventional agriculture?

Telephone interviews with five farmers were carried out in 2004 in order to explore the discrepancy between their declared intention (in 1999) to revert to conventional farming and their decision to continue with organic farming as revealed in the 2002 survey (Table 3). The interviews were analyzed on an individual basis. The insights gained, together with the written answers and notes given on the 1999 and 2002 questionnaires, underpinned proposed explanations for the differences between actual and intended behavior.

In the 2002 survey, three of the respondents cited their personal concern for environmentally friendly production methods as the main reason for their decision to stay in organic farming. In one of these three cases, the behavioral discrepancy was explained by the fact that the farm was taken over by the farmer's son in the period between the two surveys. The farm now rents rooms out to vacationers under the motto 'Organic farm vacations' thus giving organic farming an additional function in the business. The new farmer also converted to suckler cow production and modified the animal housing to conform to organic requirements. He is relatively environmentally aware: '*Organic farming should be supported ... you have to do something for the environment and not just talk about it.*'

Another farmer revealed in the 2004 telephone survey that she had ticked the box 'Abandon organic agriculture' by accident in 1999. Her attitude is clear from the following quotes: '*... only organic farming methods—I wouldn't even consider anything else. We farm organically out of conviction and not just for the money. I don't want to use pesticides.*' '*My successor should have the opportunity to take over an organic enterprise.*'

In the third interview, the farmer emphasized his dedication to organic farming: '*I'm an organic farmer with all my heart, but it's getting harder and harder. I'm against pesticides, but when it's not financially viable, a big heart doesn't help. ... We're in an isolated valley so they won't collect the organic milk, which I can understand. I'm selling the organic milk on the conventional market, I've never sold an animal as organic and last year there was the drought. But the animal feed has to be 100% organic—it just doesn't work out financially!*'

Another respondent revealed that a problem with his organic farming association in 1999 was the reason why he indicated an intention to return to conventional agriculture: '*But the issue has since been resolved, without any sanctions, and so there's no longer a reason to stop farming organically.*'

In the 2002 survey, one farmer gave a single reason for staying in the organic farming program, namely that environmentally friendly farm production was still an issue of personal interest and concern for him. In the telephone interview, the same farmer indicated that he was again thinking of abandoning organic farming come 2005: '*I'm going to give it a go until 2005, because it has its advantages. I've got a lot of ecologically-valuable land and there are big subsidies for that—that's the main reason. But I'm almost certain to abandon organic methods in 2005 ... keeping livestock is the problem, what with the new animal husbandry legislation, loose-housing systems, etc.*'

One common feature of all five interviews was that the main reasons why the farmers remained in organic farming were nothing to with some change in the relative weight attached to those reasons originally given in 1999 for planning to leave organic farming. Instead, two respondents were driven to remain organic because of a strong personal

motivation to act 'ecologically', in combination with plans and developments concerning a transfer of farm ownership. In the other three cases, it is suspected that the recommitment to organic farming was due to a positive inertia brought about through social integration within the wider organic farming movement and community.

Research issue 6

What insights into the role of environmental attitudes in the decision to remain in organic farming can be gained from the surveys?

The analysis of this issue took as its empirical basis seven farms belonging to the undecided group in 1999 who cited over 50% of the listed potential reasons for leaving organic agriculture as relevant, and whose ratings of these reasons produced a weighted average $\geqslant 2.5$ (Fig. 2). The actual answers to the question are drawn from the results of the 2002 survey and the telephone interviews conducted in 2004.

In the 2002 survey, five of the seven 'undecided' farmers in question indicated that their personal interest in, and concern for, environmentally friendly production methods was a factor in their eventual decision to remain in organic farming. Three of these farmers gave this reason as the main reason. In one case, this ecological motivation was closely tied to the transfer of farm ownership from one generation to the next, as this handwritten note on the questionnaire proves: '*I'm always going to farm organically on those few hectares that I own, so that I can pass on a healthy soil to my descendants ... the production of healthy food is something I hold dear to me.*'

All seven farmers stated that the economic situation for organic farming is improving and that they are getting used to the organic inspections. However, only 2 of the 7 'undecided' farmers cited economic reasons alone for remaining in organic agriculture. For the majority of those farmers who were undecided, but tending toward abandoning organic methods, it can therefore be assumed that the motivation to remain organic came from a combination of their attitude to environmental issues and an improvement in the economic situation.

Discussion and Conclusions

The intention of this explorative study was to contribute to the discussion about factors that influence farmers' decision processes toward or against organic farming. It drew its insights from several different surveys and does not intend to inform about statistical distributions within all Austrian organic farmers. The following discussion tries to unfold the matching patterns of values and preferences that underly the decision-making process.

Intended and actual behavior

A comparison was made between the intended and actual behavior of farmers belonging to three categories, as defined by their intended behavior in 1999 with regard to continued participation in organic farming within ÖPUL: *plan to continue participation*, *plan to end participation*, and *undecided*. There is a clear connection between the intentions expressed in the 1999 survey and the actual decisions taken later. A far greater proportion of those farmers who planned in 1999 to eventually leave organic farming did so than did farmers who were either undecided or who had planned to remain in organic farming (Fig. 4).

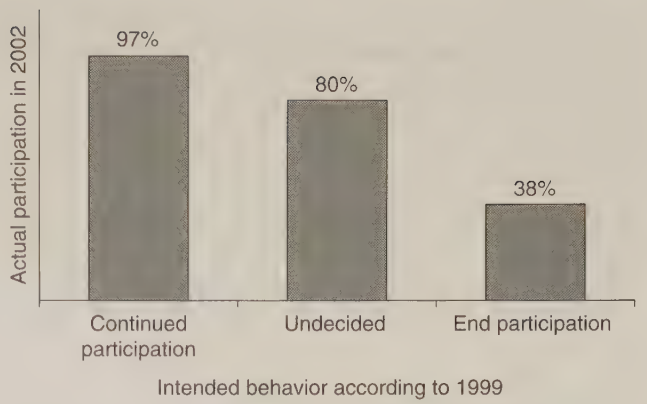

Figure 4. Actual participation in the organic farming measure within ÖPUL in 2002, in relation to intended participation according to the 1999 survey.

However, the subjective rating of possible reasons for wishing to abandon organic agriculture was not an adequate indicator of the later behavior of each individual farm. This may be partly explained by weaknesses in the research method. In aggregating results, each potential reason is weighted equally when calculating averages. The farmer may regard any one reason as relevant, yet its actual importance in the final decision may be low. This suggests that a survey should not only ask whether each listed reason is relevant, but also ask whether, and to what extent, it is important to the actual decision-making process, if more detailed conclusions are to be drawn from the results.

It would seem that the first time many farmers addressed the issue of whether they would continue in organic farming was when they were asked the relevant question in the 1999 survey. The survey was also an opportunity to articulate disappointment or frustration. Accordingly, farmers who had not yet made a concrete decision may have tended to describe themselves as undecided or planning to cease participating in organic farming. Since environmental attitudes were not addressed directly within the 1999 questionnaire, the respondents may not have taken enough account of their own environmental views when describing their intentions.

The earliest time at which farmers had to take a final decision regarding their continuing participation in the organic farming measure of ÖPUL was the end of 1999, 6 months after the survey was conducted. The option to extend participation in ÖPUL 1995 by a further year gave

farmers the opportunity to gain another year's experience with organic inspections and observe new developments in the market for organic products. There were also improvements within ÖPUL 2000 in terms of both subsidies for grassland enterprises and administrative requirements. Telephone interviews also identified changes in personal situations and the social environment. As a consequence, the final decision taken by farmers on their participation was based on more comprehensive information and—in most cases—a longer period of thought and consideration.

Reasons for abandoning organic farming methods

Far fewer reasons played a role in the actual decision to discontinue organic farming practices than were cited in regard to the intended decision to do so. This was especially true of those reasons that could be categorized under the factor *value added*. This may have been due to changes within the operating environment, but also to farm management decisions (e.g. reduction in the use of purchased feed).

There are many reasons why farmers chose to abandon organic farming. The small number of farms examined disallows quantitative conclusions, but some trends can be drawn out nevertheless. All four farmers whose actual reasons for ceasing organic farming could be categorized under the factor *organic regulations* were part-time farmers. One explanation for their decision could be that the administrative demands of organic farming are disproportionately high on small part-time farms. In a study in the Austrian province of Tyrol, frequent inspections were identified as an important reason for small farms to abandon organic farming[14]. For such farmers, the meaning and necessity of guidelines and inspections need to be communicated convincingly. The design of such guidelines might also need to take better account of the needs of small farms.

Two of the four part-time farmers who originally switched to organic agriculture because of their environmental awareness saw no future for their farms in organic farming by the time of the telephone interviews. Their change in behavior is primarily due to deep dissatisfaction with the existing organic regulations. Farmers should receive comprehensive advice and information on the consequences of converting to organic agriculture. This should cover market opportunities, production restrictions and the consequences of organic regulations. The fact that 10 of 13 farms who left organic agriculture could not envisage ever returning to organic methods suggests that there are some deficits in this area.

Those enterprises whose reasons for leaving organic farming could be categorized under the factor *management* left the sector because of the age or health of the farmer. The farmers involved made their decision independent of the actual nature of the farming methods they were using. As such, they cannot be considered to have abandoned organic farming in the classical sense. It is therefore largely impossible to find measures that would keep such farms in organic farming.

On the larger farms, economic reasons—particularly too low product prices and high feed costs—were major contributors to the decision to revert to conventional farming methods. As a result, measures that lead to higher product prices or lower feed prices would prevent such farms from leaving the sector. However, these farmers also cited reasons to do with other factors, so complementary measures would also be needed to improve the acceptance of inspections and make farm management easier.

It is interesting to note that reasons to do with production and technology were mentioned by none of the farmers as being involved in the actual decision to stop farming organically. This reflects the 1999 survey, which also suggested that such reasons would not play a key role in the decision-making process.

The role of environmental attitudes

Environmental attitudes played a major role in the decision to remain in organic farming on those farms that were prepared to live with the fact that their organic farm has financial disadvantages when compared to the conventional equivalent. A substitution effect between inner (intrinsic) and outer (extrinsic) behavioral motivators can be recognized[15,16]. If the farmer has an intrinsic willingness to behave in an ecologically friendly way, then this motivation should be accounted for in the support given to organic agriculture. An appropriate means of doing so would be through problem-related consultations, with the joint development of solutions. These advisory measures must accompany financial support measures, in order to prevent the displacement of the internal motivation by the external motivation that a purely financial support effort would produce[17,18].

The role of the family tradition

The tradition of passing on the farm to the next generation was a strong motivator behind the decision to stay organic for both those who were undecided in 1999 and those who expressed an intention to leave organic farming. The passing of a farm from generation to generation encourages sustainable or organic farming methods. The combination of the motivations family tradition ('*The farm should stay in the family*') and ecologically sustainable management ('*organic methods are the only option for me*') can be described as a primarily ecological and traditional motivation in agriculture[19]. With this approach to organic farming, the so-called successor effect causes the current farmer to consolidate and protect these farming methods. This is different to the other kind of successor effect[20,21], where the consolidation of organic farming methods after the transfer of ownership is largely based on the actions and value system of the successor.

Social embedding

The analysis of those farms who intended in 1999 to eventually abandon organic farming, but did not do so, provides indications of the effect of social embedding on behavior[18,22–24]. If you have an established position within the family, neighborhood, clubs and associations as an organic farmer, then this social embedding can encourage constancy in behavior, even where there are several reasons for abandoning organic farming, which may even have been articulated in a survey at some point. If you feel a 'social' obligation to organic farming, then it is difficult to 'leave'. In addition to attitudes, knowledge and current behavioral intentions, Maloney and Ward[25] see environmental behavior to date as a key determinant of future behavior. The greater the proportion of organic farms in the relevant area, the further you get from the conversion period, and the greater the continuing importance of the role as pioneer, the stronger the effect of this social obligation.

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A two-level unreplicated factorial experiment to determine the effect of organic and inorganic fertilizers on dry matter yield of permanent pasture

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Abstract

In organic pasture systems, the balance of soil fertility is maintained by maximizing the cycling of on-farm nutrients. In this study, the effect of fertility management on dry matter yield in organic pasture systems was examined using an unreplicated 2^5 factorial design. The factors were nitrogen (N), phosphorus (P), potassium (K), compost and seaweed extract, each at two levels (with [+] and without [−]). The trials were conducted in 2000 and 2001 at two fields on an organic dairy farm in Nova Scotia, Canada. The pasture mix is predominantly perennial ryegrass, orchardgrass and white clover. The fertility treatments were applied in spring, and forage yield was collected from early-, mid- and late-summer harvests. The analysis revealed the significance of several interaction effects, which varied considerably from harvest to harvest. Both +N and +Compost treatments were associated with increased yield. High levels of P and K already present in the soil either diminished or varied the effects of P and K treatments. Seaweed extract enhanced the effectiveness of N and compost, but reduced yield when used alone. The results suggest that the commonly recommended use of seaweed extract for organic pasture management can be detrimental to biomass production unless sufficient nitrogen is provided. Despite the unusually dry weather in the 2 years, the study demonstrated the applicability of unreplicated two-level factorial experiments in agricultural field studies.

Key words: compost, seaweed, Lenth method, organic pasture

Introduction

Permanent pasture, both natural and cultivated, represents one quarter of global land use, making it the world's largest crop[1]. Fertilizer inputs are widely applied to annual crops[2] but fertilizer application is less common for pasture land[3]. Improving soil fertility in pasture offers numerous benefits including increased yield, faster re-growth and improved forage quality. These changes ultimately influence livestock preference and ability to digest herbage[4,5].

Where pasture or forage is part of a concentrated animal production system, overfertilization via animal wastes is a potential problem. Nutrient inputs to farming systems can exceed outputs, resulting in the nutrient loading of farm soils. Since manure has a higher P : N ratio than that needed by plants and since farmers frequently apply manure to meet N requirements of plants, it is common for farmers to apply excess P with manure. In such cases, increased crop uptake of P can reduce environmental problems[6].

There are two important general theories that relate fertilizer application rates to yield. The first is the limiting factor theory where a specific nutrient applied to a growing crop results in lower yields than would be possible with an optimum application of the nutrient. The nutrient to which the crop responds can be considered deficient[7]. The second theory relates to the sustainable cycling of inputs and outputs. On a carefully managed pasture, nutrients cycle from soil to plants to animals and through their excrement, to soil. With the addition of N, via N_2 fixation in forage legumes, to balance N losses and N exports in milk and meat, the nutrient concentrations of the system tend to remain stable. A pasture system once in balance may not require commercial fertilizer inputs, especially if grazed animals consume feed supplements from off-farm sources.

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Up to 70, 80 and 60% of N, P and K, respectively, may pass through animals from their feed, replenishing soil fertility[8].

Several authors[9,10] have evaluated the role of major plant macronutrients (NPK) in pasture, but there remains a need for further comparisons between inorganic sources of macronutrients and organic fertilizer sources such as manures, composts or seaweed extracts. One study[11] compared chicken manure, inorganic NPK and compost, and found that all treatments gave comparable forage yield; however, compost-supplied P and K were not used efficiently by forage. This implies that the use of poultry compost in pasture may result in high run-off levels of P[12]. Similar findings[13] were noted with regard to compost-supplied P, suggesting that at input levels required for forage N response, P is supplied in excess. Although a study by Edmeades[14] that reviewed multiple seaweed trials found the low level of macronutrient applied through seaweed products is ineffective for increasing crop yields, seaweed fertilizers such as Tasco, Kelpak and Seasol continue to be marketed as having both beneficial microelements and growth regulators, such as cytokinin[15]. Seaweed-based fertilizer can increase antioxidant levels in forage crops and improve the quality of forage-fed beef[16]. Warman and Cooper[11] and Muir[13] remarked that nutrient availability in organic amendments depends on factors such as optimal precipitation and the time and depth of their incorporation. This further complicates comparisons to inorganic fertilizers which are generally available more quickly. These studies document the challenges associated with supplying multi-nutrient fertility to crops with organic amendments. The components (N, P, K, micronutrients and organic matter) in organic amendments are beneficial when supplied in the correct ratios necessary for plant nutrition, but may be detrimental if applications create nutrient imbalances.

In order to gain a greater understanding of fertility issues in pasture and organic systems, it is necessary to devise studies that can assess the response of forages to inorganic fertilizers and organic amendments. There are many factors influencing pasture systems, and there are no simple formulas for fertility management. Indeed, there is a lack in the understanding of relationships among essential nutrients. Although unique characteristics of each farm system are complex, by studying the role of specific nutrients (such as N), we are better able to make management decisions. To get a better understanding of the system, it is important to assess how several nutrients interact in factorial field experiments to help explain the role of a specific nutrient. The main problem in designing such experiments that involve several factors (each with two or more levels, and with more than one replications) in agricultural field experiments is the requirement of large number of similar experimental plots[17]. Lack of such similar experimental plots often forces researchers to limit the number of factors studied jointly, which will inevitably make them unable to determine the significance of important interaction effects.

In this paper, we demonstrate the design and analysis of two-level unreplicated 2^k factorial (a single replicate experiment to study k factors, each with two levels, jointly) experiments that would address this problem. For our experiment, this design required only 32 plots and allowed us to determine the main and interaction effects of five nutrients (N, P, K, compost and seaweed extract) on forage yields in an organic farm.

Although two-level unreplicated 2^k factorial designs are very common in industrial experiments, especially when there are several factors that need to be studied jointly, they are not common in agricultural experiments. The obvious advantages of such designs are: (1) cost efficiency—attained by limiting the number of levels to two and running just a single replicate, thereby reducing substantially the total number of experimental units needed for the study; and (2) reduction of experimental error—by allowing the experimenter to use more uniform experimental units (or plots of land in agricultural field studies) so that the effect of the treatments can be determined with reduced interference by extraneous variables. More details on two-level unreplicated factorial designs are given in the following section.

Materials and Methods

Experimental field layout and treatments

Experimental trials were established on two fields at the Herman Mentink dairy farm in Grand Pre, NS, Canada (45°12′ N, 64°38′ W). The fields have been in permanent pasture under long-term organic management, since 1988. Soil at the Mentink farm is Acadia silty clay (Gleyed Regosol), and is known to have relatively high P and K because the farm used manure from livestock fed high-P feeds[18]. Preliminary soil N data were not available because there is no recognized soil N test in Nova Scotia.

Following the recommended practice for soils in eastern Canada, to avoid acidification, a maintenance level application (2 t ha^{-1}) of calcitic limestone was applied to the fields in the spring of 2000 and 2001 before the experiments began. The Mentink pastureland is approximately 50% perennial ryegrass (*Lolium perenne* L.), 30% orchardgrass (*Dactylis glomerata* L.) and 20% white clover (*Trifolium repens* L.).

In each of 2000 and 2001, the experiment was set up as a 2^5 unreplicated factorial, on 32 plots on the Mentink farm for the 32 treatment combinations of the five factors, namely N, P, K, dairy manure compost and seaweed. Plot size was 3 m × 4 m, and the treatment combinations were assigned to the plots randomly. All factors had two levels (with and without) indicated as plus (+) or minus (−) in the remainder of this paper. At the request of the farm owner, we kept the chemical treatments used in the trial within the range of rates typically supplied by organic amendments. Treatment rates in the experiment were: (1) 35 kg N ha^{-1} (103 kg ha^{-1} ammonium nitrate NH_4NO_3);

Table 1. Macronutrient analysis of seaweed extract and dairy manure compost in the experiment.

	Seaweed extract		Dairy compost		
	% Analysis	Applied ($kg\,ha^{-1}$)	% Analysis	Applied ($kg\,ha^{-1}$)	Available ($kg\,ha^{-1}$)
N	1.00	0.14	0.38	76	~38
P	0.11	0.02	0.07	14	~6
K	2.40	0.34	0.43	86	~86
Ca	1.23	0.18	–	–	–
Mg	1.46	0.21	–	–	–

(2) $35\,kg\,P\,ha^{-1}$ ($175\,kg\,ha^{-1}$ superphosphate P_2O_5); (3) $35\,kg\,K\,ha^{-1}$ ($59\,kg\,ha^{-1}$ muriate of potash KCl); (4) 14.2 liters seaweed extract ha^{-1} (Lister Seaweed Products, St. Andrews, NB); and (5) 20 tonnes of composted dairy manure ha^{-1}. Analysis of the dairy manure compost and seaweed extract is presented in Table 1. In the composted dairy manure, a general estimate is that 50–70% of N, 40% of P and nearly 100% of K are available within the first growing season after application[19], and in this experiment the plant 'available' nutrient rates were assumed to be 50% of N, 40% of P and 100% of K. The lowest availability rate for N was assumed, given the lack of moisture in 2000 and 2001 and on this basis the compost treatment rate was selected to provide N levels equivalent to the chemical fertilizer treatment. All treatments, with the exception of seaweed extract, were applied by hand in late April of each year. Seaweed extract was applied with a backpack sprayer in the first week of May of each year after the first grazing. The 2001 experiment was repeated on the same farm, but in a different field to make sure that residues from the 2000 experiment would not interfere with the 2001 results.

From each experimental plot, yield data were collected by cutting forage from two $0.25\,m^2$ quadrats to a height of 2.5 cm above soil level. The data from the two quadrats were combined for each plot. The forage was dried at 55°C for 72 h in forced air ovens, weighed to determine dry matter yield, and then converted into $kg\,ha^{-1}$. Forage was harvested while still in the vegetative growth stage, when there was sufficient available to be grazed. The harvest dates just before the cows grazed were 10 May, 14 June, 8 August and 11 September in 2000, and 22 May, 11 June, 20 July and 27 September in 2001. Following each harvest, the experimental plots were grazed by dairy cattle and then to maximize uniformity, mowed and harrowed to break apart thatched grass and cow pies, if required. Manure and urine deposition was assumed to be random and was considered as part of experimental error with a reasonable expectation that distribution was approximately uniform after successive defoliations by the end of each season, given that the stocking rate was about 70 cows on 0.4 ha per day.

Monthly rainfall amounts in 2000 and 2001, as well as the 30-year average in May, June, July, August and September at a nearby weather station are shown in Table 2.

Table 2. Monthly rainfall (mm) in 2000 and 2001 together with 30-year average at Kentville, NS. Data at Kentiville (the closest weather station, which is 15 km away from the experimental site) are obtained from Environment Canada.

Year	May	June	July	August	September
2000	58.0	46.0	72.4	36.6	58.4
2001	139.5	80.3	26.0	12.3	78.0
30-year average	91.3	81.6	81.9	90.7	86.6

The analysis of unreplicated 2^k factorial experiments

The full (saturated) factorial model of unreplicated designs cannot be analyzed using ANOVA because there are no degrees of freedom (df) for the error. To address this problem, several methods have been proposed. The first, and the most prominent one, is that by Daniel[20] who suggested using a half-normal plot (also known as normal probability plot) of the effect estimates to identify active main and interaction effects. Small (in absolute size) effect estimates falling on a straight line, behaving like normal random errors about 0, are considered inactive whereas large effect estimates falling off the straight line are considered active[17,20]. The drawback of this approach is that it involves subjectivity in determining whether a given effect estimate is on a straight line or off. To overcome this subjectivity, Lenth[21] developed a simple method, known as the Lenth method, that can aid in interpreting a normal probability plot of effect estimates.

The Lenth method is based on a $(1-\alpha)100\%$ confidence interval for each effect (contrast) given as (effect estimate $\pm$ ME). The margin of error (ME) is calculated as $ME = t_{1-(\alpha/2)}(df) \times PSE$, where PSE is pseudo standard error of the effect and the df for the t-distribution is one-third of the total number of effects. An effect whose estimate is larger in magnitude than ME is considered active at α level of significance. The Lenth method is now implemented in Minitab[22] and other statistical software such as JMP of SAS Institute. In a Minitab output such as the one shown in Figure 1, the value of PSE is given, and the active effects whose estimates are larger than the ME are identified with letters. For example, for dry matter harvested on May 22, 2001, the main effect of seaweed (E), and the interaction effects of N*P*Compost (ABD), N*P*K*Compost (ABCD) and N*K*Compost*Seaweed (ACDE) are active at the 10% level while all other effects are not.

In a paper[23] that reviewed several methods for analyzing unreplicated factorial experiments, the Lenth method was found to be simple and yet powerful. Following Montgomery's[17] recommendation that the Lenth method be used as a supplement to the usual normal probability plot of effect estimates, in the first phase of the analysis we used both normal probability plot of the effects and the Lenth method at $\alpha = 0.10$ level in Mintiab Version 14. We use the

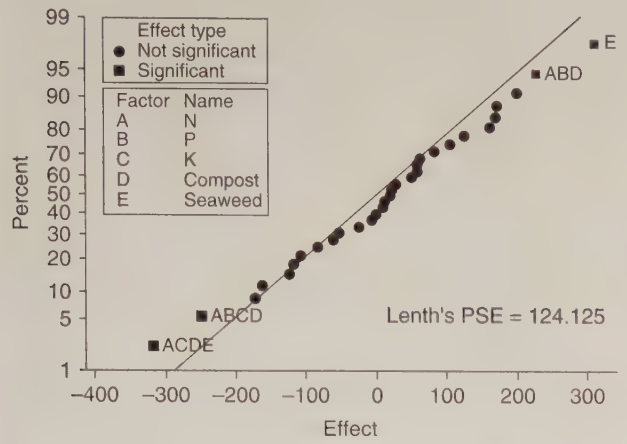

Figure 1. Normal probability plot of effect estimates (in kg ha^{-1}) together with active effects detected using Lenth's method at the 10% level for dry matter harvested on May 22, 2001.

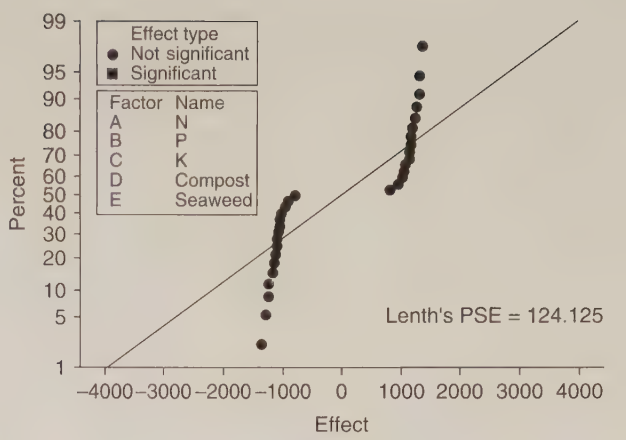

Figure 2. Demonstration of how gross error alters the normal probability plot of effect estimates (in kg ha^{-1}) for the same data as in Figure 1, but the decimal place of one of the 32 values shifted.

default $\alpha = 0.10$ because it is large enough not to neglect important effects, as well as to account for the higher variability expected in biological processes compared to well-controlled industrial experiments.

Once active effects are determined, we then complete the second phase of the analysis. This is done by either projecting the design to a replicated factorial with fewer factors (by collapsing the design by one or more factors whose main as well as all associated interaction effects are not active), or reducing the model by moving insignificant high-order interactions to the error, and then running ANOVA[17]. If an unreplicated 2^k design is collapsed by one factor, then there will be two replications resulting with 2^{k-1} df for the error; and if it is collapsed by two factors, then there will be four replications resulting with three times 2^{k-2} df for the error. However, if an unreplicated 2^k design is reduced by moving insignificant high-order interactions, the number of df for the error equals the number of interactions moved to the error. As a rule of thumb, one can proceed with the second phase of the analysis as long as the error df is at least 4. In this study, the design collapsed in the June 14, 2000, total of 2000 and June 11, 2001 harvests, and reduced in the other harvests by moving insignificant higher order interactions to the error. This second phase of the analysis can be done using either the GLM or the MIXED procedure of SAS[24]. For each harvest, the residuals were examined to verify constant variance and normal distribution assumptions of the error terms as described by Montgomery[17].

When an interaction effect, say between N and seaweed, is significant it means that the yield from the addition of N depends on whether seaweed was also added or not. Consequently, multiple means comparison is done among the treatment combinations of the highest order (the largest number of interacting factors) significant interaction. This can be done either using the least squares means (LSM) statement with pdiff option in either Proc GLM or Proc Mixed of SAS. This statement gives the LSM of the treatment combinations, and the pdiff option gives *P*-values for testing the equality of all pairwise differences[24]. To facilitate easy comparison of the treatment combinations, these *P*-values were used to generate letter groupings at the 5% level of significance for three or fewer factor interactions, and at the 1% level for the four-factor interaction that resulted in 16 treatment combinations. A 1% level for 16 means gives somewhat equivalent experimentwise error rate to a 5% level for eight or fewer means. Since for a balanced design without covariates, like in our experiment, the LSM values are exactly identical to the arithmetic means of the treatment combinations, we simply referred the LSM in the tables as means.

Drawbacks of unreplicated 2^k factorial experiments

Although unreplicated 2^k designs allow one to use similar experimental units to reduce experimental error, the results from the normal probability plot of effects and the Lenth method can be seriously affected by bad values. Bad values are extremely large or extremely small not due to the regular experimental error, but due to human error at the various stages of the experiment. Such extreme values affect the Lenth method by inflating the PSE, and hence making the detection of significant effects difficult. While the Lenth method does not indicate the presence of bad values, the normal probability plot of the effects is actually an effective way of detecting the presence of bad values. When there is a single bad value, the normal probability plot of the effects splits into two, with half of the values above zero and the other half below zero. This behavior is demonstrated in Figure 2, which is constructed using the same data used in Figure 1, but one of the 32 values changed from 1992.0 to 19920. We changed 1992.0 because it was the closest to the average of the responses; and we changed it to 19920, because ignoring the decimal place is a very likely human error. When there are two bad values, the normal probability plot of the effects forms

Table 3. Mean yields ($kg\,ha^{-1}$) with letter groupings of the treatment combinations out of N*K*Compost*Seaweed and N*P*K*Compost interaction effects for May 22, 2001 harvest; and N*P*Compost*Seaweed interaction effect for September 27, 2001 harvest.

N	K	C	S	22 May	N	P	K	C	22 May	N	P	C	S	27 Sept
−	−	−	−	1738cd[1]	−	−	−	−	1766bcde	−	−	−	−	1354c
−	−	−	+	2196abc	−	−	−	+	1998abcde	−	−	−	+	2016abc
−	−	+	−	1864bcd	−	−	+	−	2260abc	−	−	+	−	1716bc
−	−	+	+	1742cd	−	−	+	+	1842bcde	−	−	+	+	2150ab
−	+	−	−	2046abcd	−	+	−	−	2168abcd	−	+	−	−	1706bc
−	+	−	+	2154abc	−	+	−	+	1608de	−	+	−	+	1756bc
−	+	+	−	1530d	−	+	+	−	1940bcde	−	+	+	−	1596bc
−	+	+	+	2364abc	−	+	+	+	2052abcde	−	+	+	+	2640a
+	−	−	−	2166abc	+	−	−	−	2586a	+	−	−	−	2236ab
+	−	−	+	1890bcd	+	−	−	+	2322ab	+	−	−	+	1796bc
+	−	+	−	2068abcd	+	−	+	−	2104abcd	+	−	+	−	1738bc
+	−	+	+	2572a	+	−	+	+	1690cde	+	−	+	+	2650a
+	+	−	−	1720cd	+	+	−	−	1470e	+	+	−	−	1318c
+	+	−	+	2442ab	+	+	−	+	2318ab	+	+	−	+	1676c
+	+	+	−	1756cd	+	+	+	−	2058abcde	+	+	+	−	2036abc
+	+	+	+	2020abcd	+	+	+	+	2086abcd	+	+	+	+	1974abc

[1] Means followed by the same letter are not significantly different at the 1% level. Unlike in the other tables, since a relatively large number of treatment combinations are being compared here, a 1% level was used for generating letter grouping to somehow control Type I experiment-wise error rate. Each mean is based on $n = 2$, and the error df was 7.
C, Compost; S, seaweed.

unusual clustering of points, which should alert one the presence of possible bad values in the data set. Other drawbacks include lack of reserve values in case some are missing due to various reasons.

Results and Discussion

Comparison of the means of the treatment combinations from the significant interaction effects, and the means of the treatments when only the main effects are significant are presented in Tables 3–6. These results are presented starting from the highest order interaction followed by lower order interaction and then by main effects.

A significant ($P = 0.031$) N*K*Compost*Seaweed interaction was observed in the May 22, 2001 harvest (Table 3). The best treatment combination that gave the highest yield was +N, +Seaweed and +Compost, but without K. The lowest yield was obtained from −N, +K, +Compost and −Seaweed. Provided that +N is added, the experimental plots that received seaweed gave relatively higher yield compared to those that did not receive seaweed. Another four-factor interaction, namely N*P*K*Compost, was also significant ($P = 0.024$) in the May 22, 2001 harvest (Table 3). While the treatment combinations involving either +N or +Compost or both enhanced yield, using either +P or −K decreased yield. Using both +P and +K with or without N sources gave intermediate yield.

A third significant ($P = 0.01$) four-way interaction (N*P*Compost*Seaweed) was observed in the September 27, 2001 harvest (Table 3). The highest yield was obtained from either −N, +P, +Compost and +Seaweed; or +N, −P, +Compost and +Seaweed. In this harvest, the combination of +Compost and +Seaweed tended to promote yield irrespective of N or P. This is further confirmed by the treatment combinations that gave the lowest yield (+N, +P, −Compost and −Seaweed; and −N, −P, −Compost and −Seaweed), both without compost and seaweed. In addition, one might speculate that compost improved the absorptive capacity of dry soil (from July and August) on receiving September rain.

Table 4. Mean yields ($kg\,ha^{-1}$) with letter groupings for the N*P*Seaweed, the highest order significant interaction effect in 2000.

N	P	Seaweed	11 September
−	−	−	1179bc[1]
−	−	+	953c
−	+	−	1088bc
−	+	+	1522ab
+	−	−	1177bc
+	−	+	1844a
+	+	−	1796a
+	+	+	1558ab

[1] Means followed by the same letter are not significantly different at the 5% level. Each mean is based on $n = 4$, and the error df was 12.

A three way N*P*Seaweed interaction ($P = 0.017$) was observed in the September 11, 2000 harvest (Table 4). The treatment combinations with the highest yield had +N with either +P or +Seaweed. Having only +P or only +Seaweed without N suppressed growth and resulted in yields less than $1000\,kg\,ha^{-1}$ (even lower than −N, −P and −Seaweed).

Table 5. Mean yields ($kg\,ha^{-1}$) with letter groupings of the treatment combinations out of N*P, N*K, N*Compost and P*Seaweed interaction effects.

N	P	June 14, 2000	N	K	Total 2000	N	Compost	June 11, 2001	P	Seaweed	July 20, 2001
−	−	920c[1]	−	−	9177b	−	−	2711b	−	−	2040ab
−	+	1438ab	−	+	10605ab	−	+	3165b	−	+	2357a
+	−	1429ab	+	−	12373a	+	−	3068b	+	−	2298a
+	+	1077bc	+	+	10385b	+	+	3885a	+	+	1641b

[1] Means followed by the same letter are not significantly different at the 5% level. Each mean is based on $n = 8$, and the error df for the four responses were 28, 24, 28 and 11 respectively.

Table 6. Mean yields ($kg\,ha^{-1}$) with letter groupings of significant main effects.

N	May 10, 2000	Seaweed	May 10, 2000	N	Aug 8, 2000	Compost	Total 2000	Compost	Total 2001
−	1379b[1]	−	2028a	−	1188b	−	9402b	−	21731b
+	2026a	+	1376b	+	1655a	+	11868a	+	24151a

[1] Means followed by the same letter are not significantly different at the 5% level. Each mean is based on $n = 16$, and the error df for all responses was 26.

In the June 14, 2000, total 2000, June 11, 2001 and July 20, 2001, N*P ($P = 0.014$), N*K ($P = 0.038$), N*Compost ($P = 0.044$) and P*Seaweed ($P = 0.048$), respectively, were the highest order significant interaction effects. The means and their comparison are shown in Table 5. In the June 14, 2000 harvest, among the four treatment combinations of N*P, the highest yields were obtained from +N, −P and from −N, +P. The results indicate that having both or neither of N and P during such a dry month reduces yield. A similar result was observed from N and K in the 2000 total yield, with +N, −K giving the highest yield followed by −N, +K. Having both or neither of N and K reduces yield. The N*Compost interaction in the June, 11 2001 harvest indicates that having both +N and +Compost significantly boosts yield. The results for the P*Seaweed interaction in the July 20, 2001 harvest indicate that having either +P or +Seaweed increases yield, but having both +P and +Seaweed decreases yield. We cannot explain why P and seaweed together caused lower yields, nor are we aware of any studies with P and seaweed tested together.

The results for the significant main effects shown in Table 6 are for harvests with no significant interaction effect. Since the means shown for '−' and '+' levels are averaged across the levels of the other four factors, they represent overall effects of the factors. Accordingly, +N as well as +Compost significantly increased yield. On the contrary, +Seaweed significantly decreased yield during the very first harvest of 2000.

Overall, the results indicated that +N was the most consistent yield promoting treatment, and reinforced the notion[25] that N is the most commonly limiting nutrient in pasture systems. As expected, when the two levels of N were compared, +N yielded higher. The compost treatment provided N levels similar to chemical fertilizer, and acted as a yield promoter in the system. One or both of the N and compost factors were consistently present in high yielding treatment combinations.

The effect of P and K varied depending on the levels of the other factors. This could be partly due to the relatively high P and K in the soil at the farm[18]. To determine if this is the main reason why the effect of P and K varied or diminished, it may be worthwhile to do similar experiments on low nutrient soil.

The effects of seaweed extract are worthy of further investigation. Presently, there is disagreement on the effect of seaweed on yield. Several authors[16,26] argue that seaweed extract is not an effective means of increasing yield. Some authors[14,27] promote seaweed as a germination and plant-quality enhancer, but do not provide evidence of increased yields. Our results showed that adding it tends to enhance the effectiveness of N and compost.

The interaction effects that were significant varied from harvest to harvest mainly because the uptake rate of nutrients varied throughout the season as moisture varied. In dry weather, the effect of applied nutrients can be masked by moisture limitations. For example, Unkovich et al.[28] concluded that suboptimal amounts of N and water for the growth of native grassland can make responses to other nutrients unlikely. As shown in Table 2, 2000 was unusually dry in Nova Scotia, receiving precipitation below the 30-year average in all months from May through September. In 2001, with the exception of May and June that were above and close to average respectively, July and August were extremely dry. The mid-summer dry weather combined with high temperatures produced moisture stress, and reduced forage yields. This decreased treatment effects. Nearly all pronounced significant effects were in early or late summer harvests when precipitation and moderate temperatures favored forage growth.

When response measurements are measured repeatedly over a period of time like in this study, it would be useful to complete repeated measures analysis[29] to determine how the effect of the factors changed over a period of time. Repeated measures analysis was not possible in this study

because within each year, the models used in the second phase of the analysis were not similar. The design was collapsed for the June measurements (both years), and reduced by moving different terms to the error for the other measurements.

Conclusion

Treatment effects in the study vary from harvest to harvest and year to year. However, when the results are summarized, consistent trends are observable. Of all the factors, adding N clearly improved yields, though often only in specific treatment combinations. The positive effect of compost can be attributed in part to the N contribution provided by the amendment. We also speculate that this positive effect is due to its capacity to absorb moisture. There was no consistent evidence to support the idea that seaweed extract increases yield. However, using seaweed with either N or compost tended to increase yield.

The results of this study suggest hierarchal effects in the observed nutrient interactions. The effects of N may obscure the observation of all other nutrient factors. Similarly, when N is not used, the presence or absence of compost (also a good N source) may dominate yield effects. The role of P and the other nutrient effects could often only be discerned when N was not a factor.

The farm operator and host of the experiment accepted only low rates of chemical fertilizer. The low treatment rates, combined with the relatively high fertility status of the experimental site, were a limiting factor in the experiment. A clearer determination of the effect of different nutrients on forage yield in pasture systems, using an unreplicated 2^k factorial experiment, could be realized by repeating the trials in a lower fertility soil, with higher application rates, and by measuring several additional fertility indicators (covariates and responses). These include soil moisture, soil nutrient status pre/post treatment, C : N ratio, botanical species composition, forage quality and forage nutrient status pre/post treatment.

The statistical methods employed in this study were not conventional in agricultural research, but were effective and allowed observation of up to four-factor (out of five) interactions. The design's ability to evaluate complex systems with a large number of treatment combinations using few experimental units is clearly appealing. Despite the unusually dry weather in 2000 and 2001, the study also demonstrated the applicability of unreplicated 2^k factorial experiments in agricultural field studies. Unreplicated factorial designs and the two-phase analysis presented in this paper are not meant to replace conventional replicated experiments whenever enough similar experimental units are available. However, in the absence of sufficiently large number of similar experimental units, and when the chance for gross error is minimal, they can be used effectively to unlock how several factors operate jointly.

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How civic is it? Success stories in locally focused agriculture in Maine

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Abstract

Short food supply chains (SFSCs) and civic agriculture are emerging as promising means to support small and medium-sized farms, revitalize rural communities and transform producer/consumer relationships. To find out more about SFSCs and civic agriculture in Maine and to examine factors that promote their success, this study interviewed 31 successful, locally focused Maine farmers and observed many of their market outlets. The study documented the nature and extent of each farm enterprise and each marketing outlet. Farmers were asked to describe their goals, their reasons for success, what they would do differently, and what major problems they had encountered. In the interviews, key factors found to support successful locally focused farming were civic involvement in local communities, production of high-quality products tailored to customer wants and needs, vision and planning pursued in a flexible and adaptive fashion, and personal relationships with customers that foster ongoing mutual education and provide marketing feedback to the farmers. Major challenges revolve around the need for farmland preservation policies, training and financial support for new farmers, working capital for new and experienced farmers, business planning assistance, and lack of infrastructure, such as meat slaughtering and grain milling facilities.

Key words: direct marketing, locally grown food, farm stores, community supported agriculture, Maine, short food supply chains, civic agriculture, quality, customer relationships, policy needs

Introduction

On a hillside in central Maine, a farmer transplants lettuce into terraced beds and looks down at a nearby field of fingerling potatoes. 'I know who I'm planting for,' he says. He will sell the crops to customers at farmers' markets and restaurants within 40 miles of his farm.

This kind of direct marketing is on the rise nationally[1,2] as well as in Maine[3]. Thirty years ago, only one farmers' market existed in Maine and it was faltering[4]. In 2004, the state had 70 farmers' markets, up from 50 in 2002[5]. In 1989, Maine saw its first community supported agriculture (CSA), an arrangement in which members buy shares of farm products in advance and receive a portion of the harvest weekly throughout the farming season. Today, the Maine Department of Agriculture website lists 65 CSA farms[6].

Farmers who sell in direct markets and their customers, make up short food supply chains (SFSCs), linkages that set food apart from standardized products of industrial agriculture and give consumers knowledge about where food comes from and how it was grown[7–9]. Marsden et al.[7] identify three categories of SFSCs: face-to-face direct sales, products produced and sold as 'local' within a particular region, and products that convey meaningful information about their source although they are sold outside the region of production.

Several recent studies argue that SFSCs, particularly the first two types, are emerging as a promising means to support small and medium-sized farms, foster rural development, and transform producer/consumer relationships[7–10]. However, one barrier that direct sales and local product SFSCs face in the US is consumer inconvenience.

Most American consumers seek the convenient locations, hours, product variety, prepared foods options, and one-stop shopping they find in supermarkets[11–13]. Major reasons consumers give for not joining CSAs are location, extra travel, overall inconvenience, too many vegetables, and lack of advance information about what they will get[14]. When it comes to locally grown food at farmers' markets and other outlets, studies in 11 states have found major barriers to be non-availability of products, extra travel, and inconvenient hours and locations[15–25]. Most of the studies advise producers to remove or lower consumer

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inconvenience. The authors' goals are to promote farm profitability and the viability of rural communities.

Civic agriculture

Coming from a related perspective, but one in active opposition to industrial agriculture, DeLind[26] urges that researchers and practitioners pay attention to engaging consumers in political action and education around the environmental, human welfare and community aspects of local food systems. DeLind and others[26–29] see these objectives as critical components of civic agriculture.

Civic agriculture, so named by Lyson[30], is an agriculture and food production system that is grounded in a place, relies on local resources, serves local markets and customers, and is committed to social justice, ecological sustainability and 'mutually supporting social relations'[27]. Civic agriculture values cooperation over competition and quality over quantity[27]. One theoretical foundation of civic agriculture lies in Goldschmidt's 1947 study that compares two California communities, one of large and one of small farms, and finds in the latter a higher quality of life coupled with greater civic engagement[27,31].

Another foundation lies in the writings of Polanyi, who faults capitalism for separating social and political relationships from the market economy[27,32]. Lyson notes that, although neoclassical economics insists on this separation, 'the richness, multidimensionality and civic qualities of economic life in rural America never disappeared'[27]. Civic agriculture, by definition, integrates—or re-integrates—society, polity and economy.

In an article that has influenced much recent scholarship on the economic sociology of food systems, Granovetter[33] writes that activity in the marketplace, as in other realms, is 'embedded in concrete, ongoing systems of social relations'. Granovetter gives many examples in which an economic relationship informs a social relationship at the same time that the social relationship informs the economic. In more recent studies, the experiences of buyers in direct sales and local product SFSCs show this same pattern of interaction. From the buyer's perspective, personal knowledge of the producer, and information gained through conversation with him or her, adds value to the product, builds trust in its quality, and engenders support for the producer[7–10,34–36].

However, when recent studies examine marketplace social relationships from the producers' perspective, the studies address only how the economic informs the social. They note, for example, how farmers take pride and satisfaction in selling to customers who know them and value their products[36,37]. The current literature does not discuss whether or how social relationships with buyers provide information that influences the economic aspect of the producers' relationships with the buyers.

Another theme of current literature is potential divergence of SFSCs from civic agriculture. Researchers caution that SFSCs are not necessarily more environmentally sound or socially just than industrial agriculture. Smaller-scale, 'local' farmers may be poor environmental stewards, pay low wages to their workers, and provide poor working conditions[38–40]. SFSCs are often unaffordable for low income people[39–42]. Goodman[39] writes of the 'danger of a new multitiered food system differentiated by income and class' and Hinrichs sees a tension, from the viewpoints of both farmers and consumers, between social and economic goals. She cautions that embeddedness—the integration of social and economic connections—does not preclude exploitation[42]. In addition, DeLind[26] warns against equating production and consumption, on the one hand, with citizenship on the other. She notes that civic engagement requires personal sacrifice and 'is decidedly inconvenient'.

Whether or not SFSCs embody civic agriculture, there is a danger that they may be co-opted by large-scale industrial agriculture. Lyson[27] envisions that, if present trends continue, the farms and food processors of civic agriculture will expand and 'fill the geographic and economic spaces that have been passed over or ignored by large-scale industrial producers'. However, others note that conventional food business is already in the process of subverting and incorporating SFSCs[1,7,36,39,43].

What contributes to the success of successful direct sales and local product SFSCs? How fully do these SFSCs achieve the objectives of civic agriculture? Are there ways for these SFSCs to prevent co-option by industrial agriculture? In the summer of 2002, the author set out to search for answers to these questions through an examination of successful locally focused agriculture in Maine.

Methods

The author asked three authorities on Maine's SFSCs to name farmers who exemplified success in local and regional food production and marketing. They suggested 37 prospects for the study. The three individuals were personally familiar with many of the farms they nominated. In more than a one-third of cases, however, they knew little about the farm other than that it was a profitable business marketing to local customers outside of the commodity system.

During the summer of 2002, the author was able to arrange and complete interviews with 32 of the suggested farmers and farm families. All but one fit the definition of success used in the study: meeting the goals the farmer had set for him/herself according to the farmer's schedule for accomplishment.

All farmers gave informed consent to the interviews, which were semi-structured and open-ended, each about 2 h or more in length. In each interview, the farmer was asked to describe cropping/livestock systems, acreage in each crop or enterprise, nature and extent of each enterprise, and the nature and extent of each market outlet. Farmers were asked their history in farming and on their current farm.

Farmers were asked to describe their goals and the extent to which they had accomplished and were accomplishing

Table 1. Goals.

Goals/accomplishments	(*n*=31) # farms	% farms
Make a living/profit	30	97
Enjoy chosen lifestyle	14	45
Environmentally sustainable production	12	39
CSA, community connections	10	32
Quality product	10	32
Family involvement	8	26
Educate public	5	16
Get bigger	3	10
Good workers	2	6
My own place/new farm	2	6

Table 2. Categorization of 'lifestyle' goals.

Lifestyle goal	(*n*=31) # farms	% farms
Family time together	14	45
Doing what I believe in/authenticity	11	35
CSA/community coming to the farm	11	35
Entrepreneurial opportunities	6	19
Passion for what I grow/make	6	19
Working for myself	6	19
Working with apprentices/good workers	4	13
Contact with the public when selling off the farm	4	13
Working outdoors/in natural world	3	10
Exercise	1	3

those goals. They were also asked to describe their reasons for success, what they would do differently, and what major problems they had encountered.

For 26 of the 31 farms in the study, the author observed at least one market outlet. Some outlets sold products from more than one farm; in total, 21 locations were observed. Observation notes and photographs were used to document what was sold and how it was presented. At locations that were not farms and not farmers' markets, ten interviews were conducted with restaurant and health food/specialty store managers about their reasons for buying and selling the farm products.

Farmer and buyer interviews were transcribed and transcripts were analyzed. Numerical data (e.g., years of farming, farm acreage) were entered into a database. Narrative material in the interviews and in observation notes was selectively coded by topic. Recurring topics were arrayed in matrices and also clustered into categories[44,45].

The categories were used as a basis for typing goals, barriers, and reasons for success. An expert provided advice in developing typologies for the farmers' enterprises and market outlets. The matrices were used to diagram relationships among topics and to display patterns[44,45]. Topics that described the presence or absence of an interesting attribute (e.g., first generation farmer or not, upscale markets or not) were entered into a database as dichotomous variables in order to analyze frequencies of the variables and of relationships between them.

Findings

Farm and farmer characteristics

The farmers, their goals. Of the 31 participating farms, interviews were conducted with men at 14 sites (45%), with women at 11 sites (36%), and with married couples at six sites (19%). The educational level of the group is very high, compared to other Maine residents and other Maine farmers. While only 16% of Maine's general population, and 56% of its farming population, has a post secondary degree[46], 87% of farmers in the study do. Twenty-three (74%) in the study are first generation farmers. Number of years in farming ranges from 2 to 45, with a median of 17. The size of farms ranges from 2 to 1200 acres, with a median of 60.

Nineteen farmers (61%) employ workers outside of their own families. Of these, 14 (74%) mentioned without being prompted either that they pay their workers well or that they would like to pay them more.

A goal of nearly all of the farmers interviewed is to make a profit or living from the farm (Table 1). While this goal categorically covers a wide range—from 'support us and our several children and their families comfortably' to 'gross half a million dollars a year' to 'make the farm independent of my husband's income' to 'pay the bills'—economic sustainability is a major objective for almost all the farmers. Nearly all depend on the farm as a major source of family income.

The second most frequently expressed goal (45%, Table 1) is to live a chosen lifestyle. Again, this goal covers a wide range. Table 2 categorizes lifestyle goals. Overall, passion for what they do, the way they do it, and the products they produce characterizes these farmers.

The third most common goal (39%, Table 1) is to achieve and maintain an environmentally responsible production system. Consistent with previous findings that 65% of smaller, diversified, niche-market Maine farms use organic production (as opposed to 9% of Maine's larger, commodity-based farms)[46], 58% of the farmers interviewed (18) raise at least some certified organic crops or livestock. It is also notable that non-organic growers in the current study express a goal of environmental sustainability as frequently as organic growers.

Enterprises. Twenty-five of the farmers (81%) have been farming for more than 5 years. Of these, only two (8% of the 25) are producing the same products they did when they began farming.

One dairy farm has, in the past 25 years, added to its enterprises: vegetables for sale at a farmers' market, meat products, a farm store, bottled milk, cross-country skiing and tours for 7000 schoolchildren a year. Another dairy farm opened a yarn shop with natural fibers in 1990, and gradually introduced farm-baked goods, meats, produce,

Table 3. Farm enterprises.

Enterprise	(*n*=31) # farms	% of total farms (% of category)
Produce	19	61(100)
Organic mixed	11	35(58)
Non-organic mixed	6	19(32)
Non-organic apples	6	19(32)
Berries	4	13(21)
Organic potatoes	4	13(21)
Organic apples	2	6(11)
Non-organic potatoes	1	3(5)
Value-added	14	45(100)
Cheese	5	16(36)
Bottled milk	4	13(29)
Baked goods	3	10(21)
Maple syrup	3	10(21)
Cooked/canned products	2	6(14)
Dried products	2	6(14)
Ice cream	1	3(7)
Wine	1	3(7)
Yarn	1	3(7)
Livestock	13	42(100)
Natural beef	7	23(54)
Other natural livestock	7	23(54)
Organic beef	4	13(31)
Organic dairy	4	13(31)
Non-organic dairy	3	10(23)
Other organic livestock	2	6(15)
Specialty	10	32(100)
Lumber	5	16(50)
Christmas trees	2	6(20)
Compost	1	3(10)
Mushrooms	1	3(10)
Water plants	1	3(10)
Seeds	1	3(10)
Bedding plants/cut flowers	8	26(100)
Cut flowers	6	19(75)
Bedding plants/seedlings	5	16(63)
Hay/field crops	7	23(100)
Hay	6	19(86)
Organic wheat	1	3(14)
Organic soybeans	1	3(14)

canned goods made from the produce, cheese from the farm's goats and cows, natural foods, and dine-in and take-out lunches, many based on farm products. Some farms have gone in another direction, from many products to a focus on two or three high-value enterprises.

The enterprises in which the farms engage are varied (Table 3) and include almost every farm product produced in the state, from potatoes to dairy, livestock to grains, blueberries, apples, vegetables, mushrooms, wine and cheese. Nineteen of the farmers (61%) grow produce; more than half of these are organic growers. Fourteen farmers (45%) produce value-added products and 13 (42%) raise livestock, usually of more than one type. Of the livestock producers, 38% (5 of 13) raise certified organic animals.

Table 4. Typology of sales outlets.

Sales outlet	(*n*=31) # farms	% farms
Wholesale	17	55
On-farm retail	16	52
Farmers' market	14	45
Restaurants/local institutions	12	39
Health food/co-op/specialty stores	9	29
Senior FarmShare	7	23
Pick your own	6	19
Farm tours/education	6	19
CSA farm store	4	13
CSA traditional	3	10
Other farmers	3	10
Home delivery	2	6
Fairs/trade shows	2	6
Mail order	2	6
Mobile market/trailer	1	3
In-store sales promotion	1	3
Seed company	1	3

It is difficult to measure the number of enterprises per farm. Two-thirds of the farms produce at least four major products or at least 12 major types of a single product. Some farms grow 100 or more varieties of mixed produce. When mixed produce and the other subcategories listed in Table 3 are each counted as a single product, the mean number of enterprises is 3.2.

Marketing

Wholesale with a face. The most common marketing method overall is wholesale (Table 4). With very few exceptions, this means direct sales SFSCs or local product SFSCs. Whether the product is mushrooms presented by the producer at a trade show, bread marketed with the wheat grower's photograph in the advertising, goat cheese identified by farm name and location, apple pies delivered to retailers by the orchardist, or potatoes offered by the farmer at tastings in Maine and Boston stores—this is food with a face.

Farm stores, CSA adaptations, agritourism. Five farms sell through only one type of outlet. Most market through three or more types of sales outlets.

Twenty-seven growers (87%) sell directly to consumers. Nearly half sell at farmers' markets and over half sell retail on the farm (Table 4). Most of the on-farm retail outlets are more substantial than a stand by the side of the road. Nine growers, 56% of the on-farm retailers and 29% of the group overall, have a full-line store with dairy, meat, produce, baked goods and other products.

Seven farmers sell to consumers through CSAs. In 1990, a diversified farm in south-central Maine developed a modified CSA system in which farm store and farmers' market customers may buy any product at any time as a debit against a prepaid amount. 'If they pay before June,

Table 5. Reasons for success.

Reason for success	(*n*=31) # farms	% farms
Customer relationships	26	84
Quality product	23	74
Planning	19	61
Connections to community	15	48
Hard work	10	32
Technical assistance	9	29
Diversification	7	23
Workers/labor force	6	19
Not in commodities market	5	16
Family involvement	4	13
Good health	2	6
Risk taking	1	3
Price	1	3
Faith	1	3

they get a 10% discount on what they buy,' says the farmer, 'but people sign up regardless. They want to be part of something they think is a unique program that helps farms'.

Other Maine farms, including three others in this study, have adapted this CSA modification. The concept has been a model for Maine's version of the USDA-funded Senior FarmShare program in which low income seniors receive $100 shares they can redeem at participating farm stands and farmers' markets.

Six of the farms (19%) offer farm tours, agritourism, or a farm camp for children. In two cases, this is a major part of the marketing mix.

Success

Customer relationships. Connections with customers are given as a reason for success by 84% of the farmers (Table 5). These farmers know who their customers are and what their customers want. Like the hilltop vegetable grower in central Maine, they know 'who I'm planting for.'

One produce grower in southern Maine inventories the shelves and coolers of his farm store each night to evaluate demand, shift production plans, and determine what to pick the next morning. A farm store owner in western Maine greets nearly all who enter by name and readily describes favorite products of three generations of the author's relatives who live in a neighboring town: 'my steak, my baked beans, my flowers'.

The farmers engage with their customers as individuals and as sources of important information. A grower who sells produce, apples, plants and flowers at a farm store, at farmers' markets, and as pick your own sees his customers as his best source for prospective products and marketing ideas. 'You're talking to these customers all the time and that's the real advantage,' he says. 'You know what's coming down the line'. Water plants, now an important part of the marketing mix at his farm, were first offered at customer request.

Most of the farmers see their customers as a very valuable source of marketing guidance. Customers are major players in test marketing, product evaluation, and new product and service development. Customer feedback on samples, for example, determines what a goat cheese maker features as her seasonal cheeses. It was on the recommendation of a customer that a vegetable grower began planting his popular heirloom fingerling potatoes.

For most of the farmers, knowing the customer also includes mindfulness of socio-economic class and income levels. A majority (61%) sells primarily in higher income markets. In most cases, this is because the location of the market (e.g., lakeside or coastal Maine), the nature of the market (e.g., natural foods store, non-chain restaurant), or the nature of the products (e.g., organic meat, artisanal cheese) attracts upscale patronage. In at least one case, however, higher income marketing is a conscious choice. 'I'm farming to make a living for myself,' says the farmer. 'I chose an area of Maine where people with money are coming through in the summer'.

Nine farmers (29%) sell to low income seniors through Maine's Senior FarmShare program and 12 farmers (31%) sell primarily outside of upscale markets. Many farmers who sell in both lower and higher income markets have made the deliberate decision to charge lower prices in line with prices at local supermarkets when they sell in direct markets frequented by lower income customers.

Quality product. Another major reason for success, cited by nearly three-quarters of the farmers, is growing, processing, and selling products of the highest quality (Table 5). Quality delineates the market for farmers who produce specialty products such as artisanal goat cheese, dried mushrooms or premium flour. Almost all farmers in this study, however, see excellence of product as a necessity. Says one farmer of his organic potato cooperative, 'If quality isn't the number one thing, then they aren't going to have their share of the business'.

The wholesale and restaurant buyers interviewed see quality as the attribute that distinguishes products of the studied farms. 'It's better than anything else out there in appearance, freshness, flavor and consistency in quality and production, week to week to week,' says one restaurant owner/chef.

Vision and planning. Sixty-one percent of interviewees emphasize vision and planning as a reason for success (Table 5). They detail the research, piloting and assessment that goes into their ongoing business plans. Several make use of enterprise farming, a computerized system that calculates the dollar return of each crop on the farm.

Community connections. Nearly half of the farmers cite connections to the communities in which they operate as a reason for success. CSA operators express an especially strong connection, but they are not alone. Service within and on behalf of the local

community is a key factor in the lives of most of the farmers in the study—whether they are hosting community suppers, organizing a Fourth of July parade or serving on the town planning board.

Challenges

Overview. In the interviews, several unmet needs and opportunities to meet these needs emerged. Major challenges revolve around:

- Farmland preservation
- Training and financing for new farmers
- Working capital
- Business planning assistance
- Infrastructure, such as meat slaughtering and grain milling facilities.

Keeping farmland in agricultural production. Eight of the interviewees farm on the urban fringe in southern Maine. Four of these eight farms are over 25 acres. Of the four, one purchased the farm only the previous year. The other three express strong concerns about financial and other pressures from development and sprawl.

All farmers interviewed in Maine's two southernmost counties mourn the loss of farmers and farmland; most note that theirs is the last farm of its type in town. Many of these farmers make use of Maine's Farmland and Open Space Law. This law allows farmers and others who preserve open space to base property valuations on current use instead of potential development value. However, high taxes are not the only problem associated with development pressures. Inability to secure long-term leases on rented land, high costs of purchasing additional needed acreage, loss of farm supply businesses, and inability to capture the value of development rights on farm property are among the other concerns that farmers voice.

Help for new farmers. Nine interviewees have been farming for less than 10 years. Eight of these receive most of their income from farming. Of the eight, six mention problems getting start-up financing. Another concern is training and technical assistance. Most of the farmers interviewed say that other farmers have been their most helpful resource.

Access to working capital and business planning assistance. In addition to start-up financing needs, interviewees note that lack of access to working capital is a problem. Because conventional government farm credit programs are designed for commodity growers, they do not meet needs of many farmers in the study.

At the same time, most of the farmers interviewed say that planning assistance from federal, state and non-profit agencies has made a difference between success and failure. Almost all the farmers note the value of sound business planning—although some have come to this conclusion more recently than others.

Infrastructure for adding value to agricultural products. Worldwide industrialization and concentration of agriculture has led to the disintegration of small, localized processing facilities. Three years after one farmer started raising turkeys in central Maine, the slaughterhouses he had been using dropped a federal inspection program he needed to sell his birds. The farmer worked hard to put together financing to build facilities on his farm. Twelve years later he has what he needs to slaughter 4000 birds annually. But, he notes, smaller poultry producers still struggle to find a way to get birds killed and prepared for market.

Lack of facilities goes beyond slaughterhouses. Apple growers lament the loss of processing facilities for apples that are less than perfect cosmetically. An organic potato grower says, 'We've got a soup company that wants potatoes year round, but we can't store them'.

Discussion

How civic is it?

The farmers in this study have made a choice to produce and sell locally—a choice based on dedication to their communities and their customers. Five-sixths see customer relationships as a major reason for their success; nearly one-half see community connections as a key factor. These locally focused farmers demonstrate the commitment to a place and its people that Lyson[27] identifies as essential to civic agriculture.

Along with this commitment runs a parallel focus on quality. The farmers, and the customers interviewed, see quality not only as a major factor in the farmers' marketing and production success, but as a value in and of itself. The farmers also value the integrity of the natural environment. Ecological sustainability is a major goal of two-fifths of both non-organic and organic farmers in the study. Three-fifths overall raise at least some certified organic crops or livestock.

Determining whether these SFSCs meet the social justice standards of civic agriculture is more complicated. While three-quarters of those farmers who employ non-family members as workers either pay their workers well or say that they would like to pay them more, the pay is often barely above minimum wage. In many if not all cases, this is because the farmers cannot afford to pay more.

Still more problematic is the preponderance of upscale markets observed in this study. Throughout the US as a whole, the price of hand-crafted food is usually high; the clientele in niche markets is usually upper income. This is an issue for many of the farmers in the study, who want to sell to all income levels. While some go so far as to offer lower prices in lower income areas, the markets in which most of the farmers operate do not assure lower income people equal access to high-quality locally grown food.

There is another way to frame this issue, however, rather than looking to farmers to provide affordable food to all. Local food access is a policy issue that involves wider civic responsibility. Adoption and expansion of programs such as Senior FarmShare and farmers' market coupons offer a

fairer and more secure means to meet civic agriculture's social justice objectives.

What makes successful SCFCs successful?

Importance of flexibility and adaptation. Looking at case studies nationwide, Clancy et al.[47] identify four common elements of successful local food ventures in rural communities: quality product, community relationships, focused market research and financial analysis, and staying with a vision. These dovetail to a large extent with the spontaneous responses given by the Maine farmers when asked to describe the reasons behind their success.

The two sets of observations diverge somewhat, however, when it comes to staying with a vision. The visions of the Maine farmers are not necessarily tied to particular sales outlets or even particular products.

The vast majority of the Maine farmers have made major changes in enterprises and markets over the years. Indeed, it is their flexibility and adaptability that have allowed the farmers to meet their goals.

Overcoming inconvenience. The new ventures the Maine farmers have taken up usually involve marketing strategies designed to better reach customers. To overcome the barrier of inconvenience, the farmers go where the customer is—through supermarket demonstrations, trade show sales and custom deliveries.

Farmers who do not travel to consumers make it easy and attractive for customers to come to them. Full-line farm stores allow one-stop shopping. Farm-store CSAs give customers further incentive to shop at the farm.

Quality as incentive. The farmers in this study not only address the barrier of inconvenience. They also, as described above, make a very strong commitment to quality, which they see as meeting both their own needs as artisans and the needs of those who purchase their products.

Although no simple definition of quality can be assigned to local production in general[48], the farmers' perception that high-quality products are critical to attracting and retaining wholesale and retail customers accords with research findings. Across the US and in Maine, quality is the top reason consumers give for purchasing locally grown food[1,15,19,21,22,25,49–54].

What the Maine farmers mean by 'quality' is similar to the idea of 'quality' that Ilbery and Kneafsey[55] see conceptualized among producers of specialty foods in southwest England. Assessment of quality in both cases is based on producers' personal standards regarding the sensory characteristics of the product and the nature of production practices. It requires personal attention to, and supervision of, all aspects of production.

The Maine products are rarely tied to their location by the character of the product (some exceptions include 'Maine' maple syrup, heirloom potatoes and wild blueberries). Aside from farm-specific branding, the two major labels used by the farmers in the Maine study are a Maine Department of Agriculture marketing label ('Get Real, Get Maine'), which may be applied to any agricultural product produced in Maine, and an organic label, which certifies that the production process meets national standards.

What sets the Maine farmers' products apart for the consumer is not the label, but the consumer's relationship with the farmer. The farmer is part of the product—the ultimate in personal branding. Approached from the consumer's point of view, this connection with the farmer is a 'relation of regard' as described by Sage[10]. For customers of the Maine farmers interviewed, trust builds through personal experience both of the farmer's product and the farmer, including the opportunity to discuss production processes and practices face-to-face.

Competing with industrial agriculture

This personal connection, and the quality it represents and guarantees, offer a means to distinguish the product from that of industrial agriculture. Although mass produced products make wide use of farm names and attractive pictures in an effort to cash in on consumer associations between quality and local agriculture, longer food supply chains will find it difficult to replicate the presence of an actual farmer.

SFSCs allow both consumer and producer to regain control over their respective roles within the food system[36]. Success depends on the skill of the farmer at creating and maintaining the underlying relationships. The farmers in this study understand and practice the competency in relationships that Stevenson[56] sees as part of 'a human infrastructure for negotiating preferred agrifood systems'.

The case of the Maine farmers reveals a competency, unseen in previous studies, that includes transfer of economically important information in both directions. Like the businessmen that Granovetter[33] describes in his seminal article, the farmers form social relationships that inform their economic relationships with their customers.

As these farmers engage with their customers, they seek customer participation in evaluating products and services. The farmers look to customers for ongoing appraisals of product lines, product characteristics and marketing methods. In their interactions with customers, the Maine farmers solicit feedback which they use to change, adjust and refine their offerings.

The relationships between these farmers and their customers are both embedded and market-driven. The tension that Hinrichs[42] posits between social goals and economic goals was not observed by the author in interviews with the Maine farmers and their customers. For the Maine farmers, connections to community and relationships with customers serve as a foundation of economic success rather than a counterforce. As in Polanyi's[32] precapitalist markets and Lyson's[27] remnants of the rural American economic scene, economic self-interest and social embeddedness are supportive rather than alien to one another.

Relationships make the Maine SFSCs preferred markets for farmers and customers, as does the high quality of the product. Again and again, the farmers and their customers affirm the importance of where, how, and by whom the product is produced and sold.

How to support success

This study identified several policy needs that locally focused farmers see as critical to success.

- To preserve farmland, particularly in communities where farming competes with suburban and rural sprawl, requires a variety of policy tools. These include property valuation based on current use, technical and financial support to achieve diversification appropriate for changing markets, and opportunities for farmers to realize the value of development rights without sacrificing agricultural or economic viability.
- To recruit new farmers and ensure they succeed at farming requires training and financing.
- To enable both new and experienced farmers to initiate and maintain profitable enterprises requires ready access to working capital.
- To promote economic viability, wider implementation is needed of programs such as those in Maine and Massachusetts which provide selected farms with both technical assistance to develop investment-grade business plans and potential funding to implement the plans.
- To allow local production for a variety of value-added farm products requires funding and revitalization of infrastructure.

While implementation of these policy recommendations would be costly, so would the loss of locally focused agriculture. Policymakers and the public need to understand the trade-offs and figure out where their values and priorities lie.

Limitations

Only farmers who met the definition of success used in the study were interviewed. Because no comparable group of 'unsuccessful' farmers was interviewed, there is no way of knowing, based on this study, that those interviewed differ from other farmers. In addition, the sample used was one of convenience, based on recommendations from experts. Additional broader research is needed to see if the findings of this study hold in a random sample of a larger population of successful local farmers in Maine—and elsewhere.

Conclusions

A group of highly skilled Maine farmers have created and adapted successful strategies to meet their economic, environmental and social goals through active participation in local and regional food systems. Critical to this success are the farmers':

- civic involvement in local communities,
- production of a high-quality product tailored to customer wants and needs,
- personal relationships with wholesale and retail customers that foster ongoing mutual education, and
- thoughtful analysis of and detailed attention to enterprises and markets through vision and planning.

Several recommended policy changes could support farmers like those studied, rebuild connections between farmers and consumers, and make it possible for local food systems to thrive in rural and urban communities. In addition, networking and mentoring in the skills practiced by successful locally focused farmers may help others to achieve similar success.

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Residue management systems and their implications for production efficiency

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Abstract

Cotton production is the number one crop enterprise in Georgia in terms of revenue generation. However, due to continuous deterioration of soil quality with conventional tillage and chemical fertilizer application, the economic viability and sustainability of cotton production in Georgia are questionable. Residue management systems (RMSs) comprising winter cover crops were analyzed as an alternative to the existing system, which consists of conventional tillage and chemical fertilizer using yield benefit, net revenue, carbon sequestration, and yield efficiency criteria. Four different RMSs were examined for profitability and input efficiency. Four RMSs encompassing tillage versus no-till and chemical versus organic sources of plant nutrients were compared for their yield and net return differences. No-till and poultry litter with a cover crop was the only system with a positive return and crop yield based on the results from experimental data. Limited results from the experimental field were reinforced using a simulation study. When cotton yield is simulated with an alternative level of organic matter and nitrogen application, production function shows efficiency in input application at the higher level of organic matter. Regression results based on an erosion productivity impact calculator/environmental policy integrated climate (EPIC) simulation indicated that, in the long term, a no-till and poultry litter system may have promise in the region. The results from simulation confirm the results from the experimental study. This study reflected a need to change the cotton management system from the 200-year-old practice of employing intensively cultivated conventional tillage and chemical fertilizers to a new renewable resource-based system where residue management and organic sources of nutrients would be the key components.

Key words: residue management systems, production efficiency, cotton yield, organic matter

Introduction

While cotton acreage has been increasing in Georgia, cotton productivity is declining in that state and elsewhere in the United States, even with improvements in technology and increased fertilizer and pesticide applications[1]. The reason for the decline in productivity is unknown; however, decreased soil quality in the region may be one possibility. Cotton cultivation in Georgia is practiced in soil that is low in soil organic matter, a result of continuous cotton cultivation with conventional tillage for more than 200 years[2]. Both Langdale et al.[3] and Hendrix[4] agree that conventional tillage cultivation cannot be continued if future cotton production is to be sustainable and profitable.

Most cotton producers in Georgia depend on chemical fertilizers as a source of plant nutrients. Ammonium nitrate and urea are the major chemical fertilizers supplying nitrogen in cotton production. The application of chemical fertilizers such as ammonium nitrate and urea results in an increase in soil acidity. This, in turn, increases the cost of farming because reclamation is necessary for continuous cotton farming. For example, Mitchell et al.[5] report that the continuous application of ammonium nitrate in cotton cultivation required an application of lime at an average rate of 3.1 pounds for every pound of nitrogen applied as ammonium nitrate.

Conservation practices such as no-till and the use of organic sources of fertilizer have the potential to improve soil quality and stabilize cotton production in this region. Conservation practices in cotton can be cost-effective, especially given that price trends for machinery, fuel and energy, and wages are rising faster than the prices of

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chemicals[6]. It is well documented that conservation tillage improves soil quality, an effect that can be measured by organic matter content[7,8]. Soil organic matter sustains soil productivity, maintains soil structure and soil aggregate stability, increases water infiltration, and reduces soil compaction. Therefore, management practices that increase soil organic matter can automatically prevent soil deterioration and increase soil quality.

The objectives of this paper are to analyze the economics of residue management systems (RMSs) in sequestering carbon in the form of organic matter and the effect of organic matter on soil productivity and production efficiency and the overall sustainability of a management system. We define RMSs as crop management systems consisting of a cover crop in rotation with a major crop so as to supply additional residues in the rotation system. Additionally, the systems may include the no-till method and organic sources of plant nutrients.

We also assess whether the use of organic sources of nutrients and conservation tillage can increase production efficiency, profits, and crop yield. Few have calculated the return on soil quality increments in crop yield[9,10]. Others have included organic matter in the production function and calculated it as an input[11,12]. Soil quality refers to the long-term capacity of soil to function. It is true that improvements in soil quality cause better water holding capacity, bulk density, and nutrient cycling. These soil quality-related properties are highly associated with organic matter content in soil, and these desirable characteristics can increase crop yield[13–15]. Increase in yield may be the result of a change in the efficiency of inputs. Efficiency is defined as the capacity of inputs to contribute more to yield in high soil quality than when the same amount of input is applied at low soil quality. If we ignore soil quality improvement and resulting input efficiency, we may overestimate the cost or underestimate the profit from adopting the new systems. Considering the efficiency increment while evaluating alternative management systems is important because a producer can generate the same output with a lower input combination. The method suggested in this paper addresses simultaneous problems of continuous deterioration in soil productivity and the disposal of excessive animal manure. The resolution of these problems holds the possibility of increasing carbon sequestration while maintaining the soil's natural capital. Because short-term experimental results cannot provide information on occurrences over the long term, simulation results can be used to supplement this information. Data from an experimental plot on cotton production in Georgia is used along with simulation results with comparable management practices to show the role of a RMS on profitability, input efficiency, and the creation of a sustainable farming system.

Materials and Methods

To validate our hypothesis that increasing soil organic matter increases input efficiency, productivity, and ultimately economic gain, we based our study on the results of an experiment conducted at the J. Phil Campbell, Sr, Natural Resource Conservation Center in Watkinsville, Georgia, in addition to a comparable management system using a simulation program. The experimental station contains representative soil and weather for the Georgia Piedmont region. The soil is Cecil sandy loam with a 0–2% slope. The plot was planted with corn using no-till methods and a winter wheat cover crop in the 3 years preceding the start of the experiment in winter 1995.

Four RMSs were compared at the experimental site. For each management system, the winter wheat cover crop was planted in October by overseeding into standing cotton stalks. The cover crop was killed in April with a spray application of Roundup™ or Paraquat™ and mowed with a rotary mower.

The study was a factorial design in which two tillage options and two nitrogen sources were replicated three times (i.e., 12 plots). Each plot was 100 feet by 33 feet. The space between two plots was 10 feet, and the space between two replications located on the same side was 16 feet. Two replications on opposite sides were located at a distance of 30 feet.

The key management operations for each of the four systems are outlined in Table 1. A system is defined principally in terms of the method of tillage and source of nitrogen. In System 1, the plot was plowed with a chisel

Table 1. Key management operation in four systems.

Treatment	CTCF	CTPL	NTCF	NTPL
Nitrogen source	Ammonium nitrate	Poultry litter	Ammonium nitrate	Poultry litter
Fertilizer application	At planting Side dressing	At planting	At planting Side dressing	At planting
Herbicides application	At planting	At planting (Prowl™, Cotoran™, and Temik™)	At planting (Prowl™, Cotoran™, and Temik™) Post-emerge (Select™) Post-directed (Select™)	At planting (Prowl™, Cotoran™, and Temik™) Post-emerge (Select™) Post-directed (Select™)
Tillage	Chisel and Disk	Chisel and Disk	No-till planter	No-till planter
Growth regulator and defoliant	Pix™ Harvade™ and Prep™	Pix™ Harvade™ and Prep™	Pix™ Harvade™ and Prep™	Pix™ Harvade™ and Prep™

plow followed by disking. Nitrogen was applied in the form of ammonium nitrate at a rate of 60 pounds per acre. The plot was lightly disked after herbicide and pesticide applications to incorporate the fertilizer and pesticides. Nitrogen was applied at the rate of 40 pounds per acre during planting, with the remaining 20 pounds being applied as a top dressing before the cotton entered its squaring growth phase. This is considered a conventional tillage chemical fertilizer (CTCF) system.

In System 2, a primary tillage operation was conducted using a chisel plow followed by disking. Poultry litter was applied at the rate of 2 tons per acre to supply 60 pounds of available nitrogen per acre by spreading at planting. Cotton was planted with row planters. This is considered a conventional tillage poultry litter (CTPL) system. In Systems 1 and 2, a chisel plow and disk harrow were used. Three weeks after germination, the cotton in both systems was cultivated with a rototiller, which was used again a month later to control weeds. We indicate System 2 as CTPL.

In System 3, cotton was planted using a no-till planter at a row spacing of 30 inches. Nitrogen was applied at the rate of 60 pounds per acre in the form of ammonium nitrate. Forty pounds of nitrogen were applied at the time of planting and 20 pounds were applied as top dressing. *Amaranthus* and crab grass were controlled using Select™ and Paraquat™ herbicides, respectively. This system is considered a no-till chemical fertilizer (NTCF) system.

In System 4, cotton was planted using a no-till planter at a row spacing of 30 inches. Nitrogen was applied in the form of poultry litter at a rate of 2 tons per acre. This supplies nitrogen at 60 pounds per acre. Poultry litter was spread on the field using a poultry litter spreader. To control *Amaranthus* and crabgrass, Select™ and Paraquat™ were applied during the cotton growing season as post-emergent and post-emergent-directed herbicides, respectively. This system is considered a no-till poultry litter (NTPL) system.

Each system was planted with a winter wheat cover crop, and 2 weeks before cotton planting, the cover crop was killed using Roundup™ or Grammaxone™. The cover crop supplied the source of residue needed for land cover during the growing season. Cotton variety Stoneville 474 was planted in May. In each system, during the time of planting, Temik™ was used to control thrips and nematodes at the rate of four pounds per acre. Cotoran™ was applied as a broadleaf herbicide and used at the rate of two pints per acre. Prowl™ was applied at the rate of 1.5 pints per acre to control annual grass and broadleaf weeds. Pix™ was applied as a growth regulator soon after the bloom stage, and Harvade™ and Prep™ were applied as a defoliant and boll opener, respectively. Cotton was hand harvested in November to calculate the yield in each system.

Erosion productivity impact calculator/ environmental policy integrated climate (EPIC)

When sufficient experimental data cannot be obtained to estimate production function econometrically, simulation can be used to develop projected results. *Ex ante* simulation aids in the understanding of a system that does not exist or is currently experimentally impractical, or one that is in the initial stages of experimentation. Simulation methods are useful in optimizing decision making. Because real world data to estimate this kind of production function are not available, in the present study we use simulation methods to generate yields at four different levels of organic matter with nitrogen applications.

Due to various levels of physical inputs, biophysical simulation is used for generating data for biological phenomena such as crop yield. Simulation models are attractive because they can address the inherent dynamic and/or stochastic nature of agricultural problems[16]. The statistical method is an estimation technique and thus is not suitable for generating yield data using various dynamic and stochastic processes of agriculture. A bioeconomic model is a mathematical representation of a biological system that describes biological processes and predicts the effects of management decisions on those processes[17]. Several simulator packages are available to model the relationship of soil, climate, and cultivation activities to yield; EPIC is one common crop simulator. EPIC[18] is capable of simulating the complex biophysical processes of plant growth by using readily available soil, weather, and crop management information. We used EPIC to determine cotton yield response to pre-set amounts of soil organic carbon to develop cotton response functions to nitrogen under alternative levels of soil organic matter content. Specifically, daily rainfall, minimum and maximum temperature, wind data, soil information, and watershed characteristics were put in the EPIC model to simulate the crop yield. The EPIC model was calibrated so that it could reflect the county level average yield, and was then used to simulate cotton yield for representative soil organic matter content. The following is a description of three major modules of the EPIC simulation package and how they are used in our crop yield simulation model.

Soil file. This soil series number corresponding to the soil representing Georgia Piedmont (Cecil Series) was chosen from the soil list. Each soil file gives the parameters for that particular soil, which include bulk density, field capacity, sand content, silt content, organic nitrogen concentration, and soil pH. These values characterize the type of soil and amount of soil organic matter within the plowing depth.

Weather file. The weather file is chosen according to the latitude and longitude of the location and is consistent with the location of the field. The weather file provides information about rainfall, including average daily precipitation, average monthly precipitation, number of days of rainfall, wind parameters, and temperatures, such as average daily temperatures, maximum temperatures, and minimum temperatures.

Management practices file. This file contains information about the time of planting and harvesting, cover crop planting and harvesting, pesticide application,

Table 2. Treatments causing the major cost differences in the four systems.

Treatment	CTCF	CTPL	NTCF	NTPL
	----------$/acre----------			
Fertilizer	35.00	32.00	35.00	32.00
Herbicides	48.00	48.00	71.55	71.55
Machinery	196.04	196.04	164.88	164.88
Labor	29.65	29.65	27.47	27.47

cultivations, and application of fertilizer. This file simulates the management practices consistent with the experimental practices used in field experiments. We can test the yield output by varying the fertilization application rates under each level of organic matter content. This file is also used to indicate the name of the crop cultivated and to input the plant-specific parameters, such as the plant-water stress factor and the plant population crop.

Enterprise budgets for management systems

Enterprise budgets were developed based on the assumptions that an average farm is 1200 acres and the size of each plot is 40 acres. The farmer owns two tractors, a heavy tractor with a 125-horsepower engine and a light tractor with a 60-horsepower engine, along with other necessary machinery and equipment needed for cotton farming. The prices of inputs and outputs reflect 1998 prices and were obtained from various sources such as the National Agricultural Statistics Service and enterprise budgets developed by the University of Georgia Cooperative Extension Service[19]. Prices in 1998 were chosen to develop the enterprise budget. Each system is differentiated by a particular set of management operations as outlined in Table 1. The major differences in costs, and sources of those differences, are outlined in this text and provided in Table 2.

Nutrients are supplied in all systems, either through chemical fertilizers or through poultry litter. Poultry litter costs are 16.5% higher than chemical fertilizer costs. All management systems used chemicals to control insects and weeds. The selection of these chemicals represents the most common chemicals used in cotton production in the Piedmont region. In a conventionally tilled plot, herbicides such as Cotoran™ and Prowl™ were applied. Both herbicides were applied during planting. In the case of no-till plots, Fusillade™ and Roundup™ were applied as over-the-top and post-emergent herbicides, respectively. Cover crops were killed in both conventional and no-till plots using Roundup™. The cost difference of herbicides between no-till and conventionally tilled plots was 49%, with higher costs for a system containing no-till methods. Insecticides were applied at the same rate in all systems, so the cost was the same for all systems. The other major difference between no-till and conventional tillage arises from machinery use. Conventional plots are plowed and cultivated as a standard weed control practice. No-till plots are chemically sprayed, so the largest cost difference can be attributed to the difference associated with tillage, namely equipment, fuel costs, and labor cost.

The machinery use cost in Table 2 reflects both fixed and variable costs. The variable costs associated with machinery use include the cost of repair and maintenance and the cost of fuel. In the conventional tillage treatment, the total cost of machinery usage is 18.8% higher than with no-till treatments. Labor costs are also higher with conventional tillage treatments than with no-till treatments. The labor cost difference between the two treatments is 7.9% with a system containing conventional tillage costing more than no-till.

Fixed costs include the machinery cost, interest on operating capital, cost of management, and overhead cost. Interest on operating capital is calculated based on 5% of the total variable cost incurred during the production period. Cost to management is also charged at 5% of the total variable cost and reflects the opportunity cost of the farm manager. General overhead includes costs such as office expenses, sanitation service, soil analysis, and property taxes. Generally, this cost is not available, so it is assumed to be 5% of the total variable cost incurred in the production process.

Total variable cost is highest in NTPL and lowest in CTCF. The high variable cost in NTPL is due to the cost of additional herbicides. A 4% difference exists in cost between these two systems. Total fixed cost is highest in CTPL and lowest in NTCF. The use of both poultry litter and conventional tillage caused this 12.9% difference in the fixed cost between CTPL and NTCF. The total cost is therefore highest in CTPL and lowest in NTCF; net return is highest in NTCF and lowest in CTPL. The difference in net return between these two systems is 26.5%, illustrating the benefit of using no-till methods in terms of an increase in net revenue. However, the production function in any system depends on the organic matter content of the system at that time. If one system is better in maintaining organic matter, that system should produce higher profit and provide higher annual return to the cotton producer over the long term.

Results

Experimental results

Hypotheses that cotton yields differ due to tillage and fertilizer are tested using pair-wise *t*-tests, and average crop yields for each of the four management systems for all 3 years are calculated. Average yield is then compared across different systems based on the data obtained from the combined 3 years. The average yield data for all four systems for 3 years are shown in Table 3. When the average yields between two tillage systems are compared to determine whether they are significantly different, the pair-wise *t*-statistics revealed that they are significant at a 5% level. When 3 years of data are analyzed to determine if there exists a difference in yield due to a difference in

Table 3. Average yield and net return due to tillage, nutrient sources, and management systems for 3 years of experiment data in Watkinsville, Georgia, 1996–1998.

	Tillage[1]		Nutrient source[2]		Management[3]			
Variable	**CT**	**NT**	**CF**	**PL**	**CTCF**	**CTPL**	**NTCF**	**NTPL**
Net return ($/acre)	138.64	307.02	177	268.66	104.25	173.03	249.75	364.29
Lint yield (pounds/acre)	816	1059	870	1004	766	866	974	1143

[1] CT stands for conventional tillage and NT stands for no-till.
[2] CF stands for chemical fertilizer and PL stands for poultry litter.
[3] CTCF, System 1; CTPL, System 2; NTCF, System 3; and NTPL, System 4.

nutrient source, we found that they were not significant at a 5% level. However, the average yield due to nutrient sources is significantly different at a 10% level.

Average cotton yields for all 3 years are also compared to see if they differ across differing systems. Average yield is highest for NTPL and lowest for CTCF. Average cotton yields differ significantly between CTCF and NTCF, CTCF and NTPL, and NTCF and NTPL at a 10% significant level (Table 4). Average yields between NTCF and NTPL differ significantly at a 5% level. In general, it is observed that tillage contributes significantly toward yield differences. For example, the difference between CTCF and NTCF is due to tillage, which is found to be significant; however, the difference between CTCF and CTPL is not significant at a 5% level, which differs only in the sources of nutrients supplied. We have also found that the NTPL shows the highest yield and is significantly different from the other three systems when 3 years of data are analyzed.

Cost and return estimates

For the economic information on yield and cost of various operations in each management system, cost and return estimates were conducted. Cost and return estimates were calculated based on 1998 prices for both inputs and outputs. Total variable cost, income above variable cost, fixed cost, total cost, and net return for each of the systems for each year were calculated. We have shown the net return due to tillage methods, nutrient sources, and system differences for each year in Table 3. A pair-wise *t*-test was conducted to determine whether the four management systems were significantly different from each other. The results of this test are presented in Table 5 and indicate that the average net return is highest in NTPL and is significantly different from other systems. The results are obtained both from pair-wise *t*-test results and critical difference values obtained from the analysis of variance (ANOVA). The average net return between the two tillage methods was found to be significant, probably because of higher organic matter buildup in a management system containing no-till compared to conventional tillage. However, net return differences due to two different nutrient sources were found to be insignificant at a 5% level. This is perhaps because nutrients are available to cotton at the same extent, regardless of the nutrient sources. The Tukey test results for critical difference from ANOVA also indicated that average return ranks NTPL>NTCF>CTPL>CTCF. The ranking indicates that the returns are significantly different from each other. The net return comparison produced similar results to that of the yield result reported in Table 4.

Regression results

The regression models used were:

$$\text{Net return: } R_i = \alpha_0 + \alpha_1 * \text{year} * \text{dummy}_2 + \alpha_2 * \text{year} * \text{dummy}_3 + \alpha_4 * \text{year} * \text{dummy}_4 + \nu_i$$

Table 4. Hypothesis tests to find if average yield differs due to tillage, fertilizer, and management systems based on 3 years of combined data.

Comparison	***t*-statistics**
Poultry litter versus chemical fertilizer	−1.93*
No-till versus conventional tillage	−3.99**
CTCF[1] versus CTPL	−1.32
CTCF versus NTCF	−2.60**
CTCF versus NTPL	−4.02**
CTPL versus NTCF	−1.62
CTPL versus NTPL	−3.35**
NTCF versus NTPL	−1.96*

* Indicates significant at a 5% level.
** Indicates significant at a 10% level.
[1] Abbreviations outlined in Table 3.

Table 5. Test result of difference in average return due to tillage, nutrient sources, and management systems for 3 years of data 1996–1998.

Comparison	***t*-statistics**
Poultry litter versus chemical fertilizer	−1.96*
No-till versus conventional tillage	−4.05**
CTCF[1] versus CTPL	−1.38
CTCF versus NTCF	−2.77**
CTCF versus NTPL	−4.22**
CTPL versus NTCF	−1.75*
CTPL versus NTPL	−3.53**
NTCF versus NTPL	−2.02*

* Indicates significant difference at a 5% level.
** Indicates significant difference at a 10% level.
[1] Abbreviations outlined in Table 3.

Table 6. Coefficients associated with different variables in regression caused by system differences.

Explanatory variables	Coefficients associated with explanatory variables when a dependent variable is	
	Net return ($/acre)	Yield (lb/acre)
Intercept	281.30 (5.45)[1]	1026.24 (13.10)
Year	−78.80 (−2.76)	−116.12 (−2.68)
Year*dummy$_2$	25.08 (0.98)	36.35 (0.94)
Year*dummy$_3$	60.60 (2.37)	86.57 (2.23)
Year*dummy$_4$	112.57 (25.53)	163.57 (4.22)
Adjusted R^2	0.36	0.33

[1] The values in parentheses are t-values.

and

$$\text{Yield: } Y_i = \beta_0 + \beta_1 * \text{year} + \beta_2 * \text{year} * \text{dummy}_2 + \beta_3 * \text{year} * \text{dummy}_3 + \beta_4 * \text{year} * \text{dummy}_4 + \varepsilon_i.$$

Here, Y_i is cotton yield per acre, R_i is net return in $/acre, α_i and β_i are parameters of the model; dummy$_i$ is a variable used to differentiate the effect of one management system from another. Specifically, dummy$_2$ = 1 if the system is CTPL; otherwise it is zero. Dummy$_3$ is 1 if the system is NTCF; otherwise it is zero. And dummy$_4$ is 1 if the system is NTPL; otherwise it is zero. When dummy$_2$ = dummy$_3$ = dummy$_4$ = 0, then the yield and net return equations are representative of the CTCF. ε_i and ν_i are the error terms in the model. We assumed that, over the time period, the change is visible as indicated by different slopes for each system.

The result of this analysis is shown in Table 6. The coefficients obtained from the regression model confirm most of the results derived using a pair-wise t-test. The second column in Table 6 shows the results based on the net return in each of the four management practices adopted. The adjusted R^2 of the regression is relatively low: 0.36. The outcome is not surprising, provided this is pooled data comprising 3 years and four systems. All variables in the model are found to be significant, except year*dummy$_2$. This is the variable that shows the interaction between year and CTPL. This also means that the net returns between CTCF and CTPL are not significantly different over the time period, consistent with the results shown in Table 5. These two systems (CTCF and CTPL) differ only on the source of plant nutrients used. NTCF and NTPL are significantly different from CTCF and CTPL. The decline in net return over the time period is much lower than with CTCF and CTPL, although it is found to be negative in NTCF. The only difference between NTCF and NTPL is the source of plant nutrients. Since poultry litter supplies nutrients and improves soil properties, these effects become more evident when it is combined with no-till. Therefore, yield and net return are high under NTPL compared to the other three systems. NTPL is the only system that has a positive yield change over time. Overall, we found the following results for each system when the dependent variable is net return per acre:

$$\text{Net return} = 281.30 - 78.80\ \text{year} + 25.08\ \text{year}*\text{dummy}_2 + 60.60\ \text{year}*\text{dummy}_3 + 112.57\ \text{year}*\text{dummy}_4.$$

When the net return in CTCF is examined, values associated with dummy$_2$, dummy$_3$ and dummy$_4$ become zero; therefore, the above equation reduces to CTCF: $R_i = 281.3 - 78.8$*year. This helps us to understand what happens to net return if CTCF is to be continued for several years. For example, the result shows that, after the third year, net return on the cotton field with CTCF starts to become negative. Similarly, net return in CTPL can be obtained by substituting dummy$_2$ = 1, dummy$_3$ = 0, and dummy$_4$ = 0 to get the following value:

$$\text{CTPL: } R_i = 281.3 - 53.7*\text{year}.$$

This reveals that it takes more than 5 years before we obtain a negative return with CTPL. Accordingly, for NTCF, this time period extends to 16 years as obtained by replacing dummy$_2$ = 0, dummy$_3$ = 1, and dummy$_4$ = 0, when we get $R_i = 281.3 - 18.2$*year. However, in NTPL, net return increases by the amount of $33 each year as $R_i = 281.3 + 33.70$*year. The result further suggests that the positive benefit of no-till can be realized only when it is used with poultry litter. When plant nutrients are supplied by chemical fertilizers in a no-till method, the yield decline over time is low compared to the convention tillage method, but the overall change in yield is still negative. The overall slope of the net return is positive in NTPL, indicating that net return should remain positive given the cotton yield, price, and cost information used in this study. The upper plateau in the net return may be restricted by the steady-state level of organic matter.

The regression result is similar to the above case when the dependent variable in the regression is yield per acre. The adjusted R^2 value of the regression is found to be 0.33, which was slightly lower than the case of the net return model. CTCF shows yield decline over the time period. CTPL and NTCF also have yield decline over the time period, but the decline in yield is less when compared to CTCF. Although, yield decrease is slightly low in CTPL, these two systems are not significantly different, as indicated by the coefficients of the interactive variable year*dummy$_2$. CTCF and CTPL are not significantly different, but NTCF is significantly different from CTCF. The result revealed a positive impact on crop yield as NTPL is continuously adopted. In general, yield should increase by 47.4 pounds per acre—if both no-till and organic sources of nutrients are used. By placing the coefficients from Table 6 in the yield equation, we can derive a specific equation associated with each system. These are shown below for the four systems. The methodology on how these can be derived is similar to

the explanations provided for the net returns earlier in this section.

$$\text{Yield}_i = 1026.4 - 116.12*\text{year} + 36.35*\text{year}*\text{dummy}_2 + 85.67*\text{year}*\text{dummy}_3 + 163.57\ \text{year}*\text{dummy}_4.$$

For a specific system, after replacing the value of appropriate dummy in the above equation, the results are as follows:

$$\text{CTCF: } Y_i = 1026.4 - 116.1*\text{year},$$
$$\text{CTPL: } Y_i = 1026.4 - 79.8*\text{year},$$
$$\text{NTCF: } Y_i = 1026.4 - 29.5*\text{year and}$$
$$\text{NTPL: } Y_i = 1026.4 + 47.5*\text{year}.$$

Similar to the net return result described earlier, the yield result confirmed that the yield change is positive only if a no-till method is combined with an organic nutrient source. The analysis confirms that—if poultry litter is applied on the crop field using best management practices and other site-specific characters—it should provide profitable and sustainable farming opportunities. The results also revealed that it would be necessary to use no-till with poultry litter and a cover crop if cotton productivity is to be sustained in the long term.

In the real experimental data, it is difficult to decipher the reason behind the yield and net return changes because the effect is confounded by several factors. Previous research in this area has given credit to an increase in organic matter in a system containing no-till, organic sources of nutrients, and cover crops[20–22]. To test this hypothesis, we complemented the experimental results with a simulation study. The simulation results are described in the section below.

Simulation results

One particularly important input in cotton production is nitrogen fertilizer. The effects of nitrogen fertilizer at four different levels of organic matter are simulated to obtain cotton yield. These four different organic matter levels in soil are 1, 2, 3, and 4%. The lower and upper values are obtained from existing soil organic matter content in Georgia soil and the potentially maximum soil organic matter that may exist in Georgia soil[4].

Regression results of the models were estimated from the simulated yield data obtained from EPIC. Four production functions describing the relationship between input use and crop yield are compared. These four production functions are quadratic, square root, von Liebig, and Mitscherlich Baule (MB). A formal comparison of models is done by using a joint *P*-test. The joint *P*-test is a test of the restrictions that all the coefficients associated with alternative models—other than the model of interest—are, statistically speaking, equal to zero. This test has been shown to be stronger to compare the suitability of alternative production functions[23,24]. A test of the MB production function against all other production functions indicates that alternate production functions are quadratic, square root, and von Liebig, and the estimated coefficients associated with all three production functions are not significantly different from zero. Our analysis indicated that the MB production function is found to be favored over all other models. Therefore, the results found here suggest that the MB function is more appropriate for these data. Since the MB production function estimated provides the best fit for the given simulated data, we focus only on this model for economic analysis. It is assumed that organic matter causes a shift in the intercept and changes the slope of the production function. Shift in intercept means yield becomes different in each organic matter level, and the change in slope means the yield changes differently under four different management systems as organic matter increases in soil. To account for these two hypotheses, the following model is estimated:

$$Y_i = \beta_1(1 - \exp(\beta_2(\beta_3 + X_i + \gamma_2 D_2 + \gamma_3 D_3 + \gamma_4 D_4 + \alpha_2 X_i D_2 + \alpha_3 X_i D_3 + \alpha_4 X_i D_4))).$$

Here, D_2, D_3, and D_4 are the dummy variables that represent 2, 3, and 4% organic matter content in soil in a given management practice, respectively. β_i are the basic parameters of the model, α_i are the parameters that show differences in slope of the production function due to organic matter, and γ_i is the difference in the intercept of the production function due to difference in organic matter. Three models are estimated—one using all parameters in the model, one with all $\gamma_i = 0$ or $\beta_i = 0$ and the last one with both $\gamma_i = 0$ and $\beta_i = 0$. The result of this estimation is presented in Table 7. The *F*-test statistics are calculated to compare parameters between the model estimated with all α_i, β_i, γ_i, and the model with only α_i. The calculated *F*-statistic was found to be 13.4, which is significant at the 5% level of significance and $F_{6,154}$ degrees of freedom.

Table 7. Parameter estimation of MB production function using a dummy variable approach.

	MB model with		
Parameters	**Slope and intercept**	**Only slope**	**Only intercept**
β_1	717.551*	711.964*	709.44*
β_2	0.008*	0.036*	0.097*
β_3	304.244*	58.434*	19.697*
α_1	8.233*		1.532
α_2	11.836*		2.873
α_3	14.660*		4.216*
γ_1	−45.170*	1.178*	
γ_2	−42.089*	2.108*	
γ_3	−35.398*	2.936*	
Adjusted R^2	0.822	0.8	0.769
SSE	27041	31041	36944

* Indicates parameters estimated are significant at a 5% level.

Table 8. Parameter estimation of MB production function at four different levels of organic matter.

At 1% organic matter level
$Y_i = 683.1185^* (1 - \exp(-0.131717^* (17.2217^* + X_i)))$
Adjusted $R^2 = 0.9479$ SSE = 1053
At 2% organic matter level
$Y_i = 701.900579^* (1 - \exp(-0.112647^* (19.05^* + X_i)))$
Adjusted $R^2 = 0.9456$ SSE = 1525
At 3% organic matter level
$Y_i = 717.979^* (1 - \exp(-0.99414^* (20.5984^* + X_i)))$
Adjusted $R^2 = 0.9431$ SSE = 2081
At 4% organic matter level
$Y_i = 732.014^* (1 - \exp(-0.0889^* (22.267^* + X_i)))$
Adjusted $R^2 = 0.9408$ SSE = 2501

Y is cotton yield and X is nitrogen, both measured in pounds per acre.
* Indicates that parameters are significant at a 5% level.

This indicates that the cotton yield response to nitrogen at different levels of organic matter behaves like a switching function. At one level of organic matter, the parameters of the production function are significantly different from at the other level. The higher the organic matter, the higher the yield and vice versa. The result can be explained by the fact that high organic matter increases the efficiency of applied nitrogen by recycling the available nitrogen. Therefore, the MB production function is estimated for each level of organic matter. The estimated parameters for each of the four levels of organic matter in Table 8 are significant as indicated by the t-value at a 5% level. The adjusted R^2 for these models is about 94%, which indicates that the MB production function gives quite a good fit to the simulated data at each level of organic matter.

Do all systems respond to applied nitrogen in the same way for a given level of organic matter? The hypotheses indicate that within a given level of organic matter, each system performs differently when slope and intercept are also tested. First, the model associated with the hypothesis that all systems respond similarly to applied nitrogen is estimated. This is a restricted model. An unrestricted model is estimated where either slope or intercept or both differ due to system differences. Both restricted and unrestricted models were estimated for each level of organic matter. The parameters and sum of square error of an unrestricted model and the sum of the square error of the restricted models are shown in Table 9. The information from this table is then utilized to determine if the management system differs for the given level of organic matter. The F-statistics given as $F_{3,31}$ revealed that there exists a difference in the response to applied nitrogen due to management system. However, the hypothesis that yield response to nitrogen according to management systems for the given level of organic matter is different in terms of intercept is rejected. At each level of organic matter, the management system revealed a different response to nitrogen in terms of production function slope but not the intercept. Table 10 shows the hypothesis test result where models are tested for differences in slope and intercept.

The test results indicate that four management systems produce different responses to nitrogen input within a given level of organic matter. This means nitrogen fertilization enhances yield much higher in NTPL than in the three other systems.

Table 9. Effect of management systems on cotton yield at four organic matter levels[1].

At 1% organic matter level
$Y_i = 683.36 (1 - \exp(-0.18 (12.98 + X_i - 0.12\ S_2\ X_i - 0.22\ S_3\ X_i - 0.51\ S_4\ X_i - 0.03\ S_2 - 0.21\ S_3 - 0.28\ S_4)))$
Adjusted $R^2 = 0.98$ SSE = 321.17
SSE with only intercept model = 856.15
SSE with only slope model = 330.91
At 2% organic matter level
$Y_i = 702.24 (1 - \exp(-0.15 (14.42 + X_i - 0.12\ S_2\ X_i - 0.21\ S_3\ X_i - 0.52\ S_4\ X_i - 0.035\ S_2 - 0.19\ S_3 - 0.23\ S_4)))$
Adjusted $R^2 = 0.98$ SSE = 424.28
SSE with only intercept model = 1222
SSE with only slope model = 431.04
At 3% organic matter level
$Y_i = 718.40 (1 - \exp(-0.13 (15.52 + X_i - 0.12\ S_2\ X_i - 0.24\ S_3\ X_i - 0.53\ S_4\ X_i - 0.033\ S_2 - 0.19\ S_3 - 0.22\ S_4)))$
Adjusted $R^2 = 0.98$ SSE = 536.42
SSE with only intercept model = 1628
SSE with only slope model = 543.10
At 4% organic matter level
$Y_i = 732.50 (1 - \exp(-0.12 (16.72 + X_i - 0.13\ S_2\ X_i - 0.22\ S_3\ X_i - 0.54\ S_4\ X_i - 0.021\ S_2 - 0.23\ S_3 - 0.24\ S_4)))$
Adjusted $R^2 = 0.98$ SSE = 569.34
SSE with only intercept model = 1882
SSE with only slope model = 578.34

[1] System Dummies are $S_2 = 1$ if CTPL, otherwise zero; $S_3 = 1$ if NTCF, otherwise zero; $S_4 = 1$ NTPL, otherwise zero.

Table 10. Hypothesis testing of performance of four systems at four different organic matter levels.

Null hypothesis	Test statistics[1]	Conclusion
1% organic matter		
H_0: intercept coefficients are zero	0.12	Fail to reject
H_0: slope coefficients are zero	6.46	Rejected
2% organic matter		
H_0: intercept coefficients are zero	0.06	Fail to reject
H_0: slope coefficients are zero	6.75	Rejected
3% organic matter		
H_0: intercept coefficients are zero	0.04	Fail to reject
H_0: slope coefficients are zero	6.93	Rejected
4% organic matter		
H_0: intercept coefficients are zero	0.05	Fail to reject
H_0: slope coefficients are zero	7.20	Rejected

[1] Test statistics are based on $F_{3,31}$ at 5% level of significance. The critical value is 3.31.

Summary and Conclusions

This study reflected a need to change the cotton management system from the 200-year-old practice of using an intensively cultivated conventional tillage and chemical fertilizer system to a new system where residue management would be the key component. Among the four systems compared, a system with cover crop, poultry manure, and no-till faired the best. We used experimental and simulation data to validate our theory on the role of no-till and organic sources of nutrients on the long-term profitability and input efficiency of a management system. We used both the pair-wise *t*-test and the dummy variable regression approaches to show that yield and net return could be positive if no-till and organic nutrient sources are adopted in the farming system. Although we did not have the data to support this hypothesis, previous researchers have indicated that most of this change should be credited to organic matter content in the soil. To supplement the experimental data and test this hypothesis, the cotton yield relationship between organic matter content in soil under various nutrient application treatments and replications were simulated using the EPIC model. The obtained yield- and organic matter-related input efficiency is modeled using an MB production function approach. EPIC simulated data showed that the MB production function is the best fit model to describe the relationship of cotton yield to nitrogen at four levels of organic matter. The marginal product of nitrogen increased when organic matter content increased. This effect is due to the increasing ability of organic matter to recycle plant nutrients. Different management systems reached yield plateaus for different nitrogen rates. NTPL reached the plateau more slowly with respect to nitrogen than the other three systems. At the given level of organic matter content in the soil, CTCF reached the yield plateau faster than the other three systems. This analysis revealed an increasing yield response to nitrogen with an increase in organic matter.

Most farmers in Georgia believe that the no-till and organic manure system is unprofitable; however, it was found that farmers have incomplete information about the long-term benefits of this renewable-based system, particularly its ability to increase organic matter in a long run, reduce the dependency on fertilizer, and reduce petrochemical resource use (no-till results in a reduction of machinery expenses by as much as 18.8%). The study observed that the relatively low machinery expenses (including costs for fuel and lube) associated with a no-till method enabled it to better survive when and if a fuel tax is implemented to curtail global warming. The management system containing no-till, poultry litter, and a cover crop generated more organic matter than any other practice, and in the long run produced a level of organic matter higher than the original level of the management system. Given all these facts, it was apparent that the system would provide long-term sustainability.

When considering other crops, environmentalists and economists should emphasize similar systems that are capable of sequestering carbon and emerging as a sustainable agricultural system. It is also likely that crops such as sorghum, corn, and soybeans would realize even greater benefits with this conservation system than the results produced with cotton. Even so, cotton, which is a low residue-producing crop, fared well in this study. Adoption of the management practices outlined in this study should help the United States meet the carbon dioxide emission reduction goal set in the Kyoto Protocol and at the same time develop a sustainable farming system.

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Organic apple production in Washington State: An input–output analysis

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Abstract

This paper provides an input–output (I/O)-based economic impact analysis for organic apple production in Washington State. The intent is to compare the economic 'ripple' effect of organic production with conventional production. The analysis is presented in two scenarios: first we compare the economic impact of organic versus conventional apple production for a final demand increase of US$1 million as measured in sales. In the second analysis, the economic impacts of organic and conventional apple production are compared in terms of a given unit of land (405 ha of production). Both state-wide output (sales) and employment (jobs) impacts are estimated under each scenario. Results are presented in terms of direct, indirect, and induced economic impact. Organic apple production was more labor intensive than conventional production. While the organic apple sector used less intermediate inputs per unit of output than conventional production, it also produced higher returns to labor and capital. As a result, the indirect economic effect was lower for the organic sector than the conventional sector, but the induced economic effect was higher for organic. Given the organic price premium, the economic impact (direct, indirect and induced) was larger for organic apple production than conventional apple production.

Key words: conventional and organic apple production, multiplier effects, output, employment effects, IMPLAN

Introduction

In recent years, organic food production has been growing dramatically both in the USA and the world. Worldwide, more than 100 countries were producing organic food with about 24 million hectares (ha) of land under organic management in 2004. The global organic food industry reached US$23 billion in 2002. This trend is likely to continue in the near future as organic food demands increase in Europe and North America[1].

Before further discussion, the definition of organic should be presented. According to the Organic Trade Association (OTA), the National Organic Standard Board defined 'organic' as follows[2]:

> Organic agriculture is an ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity. It is based on minimal use of farm inputs and on management practices that restore, maintain and enhance ecological harmony.

Sales of organic products in the US have increased steadily during the past 10 years and reached US$10.38 billion in 2003. The annual growth rates have been between 17 and 21% since 1997[3]. With this growth rate, the OTA projected that retail sales of organic products would be US$20 billion by 2005[4]. Numbers of buyers of organic products have also increased in recent years. The Hartman Group[5] reported that about 66% of US consumers bought organic products in 2004 compared to 55% in 2000. One of the many factors driving the surge is increased availability of organic products in mainstream markets. For example, about 20,000 conventional grocery stores were selling organic products in 2003[5,6]. *As consumption of organic products increases, so do areas of organic production.* Areas of certified organic land for major crops and pastures in the US increased by about 0.5 million ha between 1997 and 2001 and reached 0.93 million ha in 2003[6]. The organic food industry in Washington State (WA) has also increased. From 1988 to 2004, organic apple production grew 100-fold from a US$2.5 million industry to a US$250 million industry. However, organic agriculture still represents less than 2% of the state's agricultural production[7]. Among organic crops production, apples have the largest organic certified land area in WA. The certified area of apple production was 2836 ha in 2003, increasing from 44 ha in 1988[8].

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Organic apple production has expanded in WA due to market forces as well as advances in organic management. Strong consumer demand maintains a premium for organic apples, while producers are receiving a lower price for conventional apples. Also, improvements have been made in controlling coddling moth in apples with organic methods[9]. Moreover, organic apple production has fewer environmental impacts, can be more profitable and is more energy efficient than conventional apple production[10].

The purpose of this study was to compare the economy-wide economic impact of organic apple production with conventional apple production using an input–output (I/O) model of the WA economy. One of the issues that arises with organic production methods is the economic impact in the broader off-farm community. Less use of off-farm, industrially produced inputs with organic production would lead to smaller economic ripple effects off the farm. Organic production, however, may generate larger returns to labor and capital that would lead to larger off-farm economic impact in the form of household consumption (induced effect). This study provides empirical measures of both the indirect and induced economic impacts and thus permits comparison of the economy-wide economic impact of organic and conventional apple production.

To our knowledge, no economic research has been done on the economy-wide economic impact of organic apple production. However, the economic impact of other crops has been assessed. Dobbs and Cole[11] conducted a study of the economic impact on a rural economy of converting from conventional to sustainable farming systems in five different regions of South Dakota. The study found that conversion from conventional to sustainable farming systems caused both negative and positive changes in income of the agricultural household, purchases of input supplies, and consumer expenditures. Both on- and off-farm incomes were analyzed in the study. On-farm incomes declined in four out of five regions as result of conversion from conventional to sustainable farming systems. When organic price premiums were included, on- and off-farm income increased in three of the five regions.

Model Development

The I/O model in this paper is based on the IMPLAN (impact analysis for planning) Professional™ (IMPLANpro™) data and Version 2.0 software. The model represents the Washington economy for 1997. The analysis is divided into two parts: (1) the economic impact of a US$1 million increase in final demand of each sector and (2) the economic impact of a 405 ha (1000 acres) increase of each sector. The I/O analysis is presented for a Type SAM model. Social Accounting Matrix (SAM) is an extension of I/O accounts to include more detail on the distribution of factor market income to households and other institutions. With a SAM tracing the flow of income from industries to households, a Type SAM economic model may be constructed that shows how changes in industry income translate into changes in household income and consumption. In this model, both household income and household consumption are treated as endogenous. This model allows induced income effects to be measured in an accurate and consistent manner. For a more complete description of the technical details of the economic model, see Appendices 1 and 2.

Data sources

The following three major sources of data were used to construct the economic model and conduct the analysis.

IMPLAN. First, the WA I/O model used 1997 data from the WA IMPLAN database, the most recent data available at the time this study was done. The IMPLAN Group obtained these data from various sources, including the Bureau of Economic Analysis's Regional Economic Information System, Bureau of Labor Statistics, Bureau of Economic Analysis Benchmark I/O Accounts of the US, US Bureau of Labor Statistics ES202 Program, National Agricultural Statistics Service, and Census of Agriculture (p. 227–237)[12].

Glover et al. The second source of data was from the Glover et al.[13] study in which conventional, integrated, and organic systems of apple production were compared. Enterprise budget data for conventional and organic apple production collected from this study were converted to I/O production functions for both conventional and organic apples in order to estimate the cost and value of production of both conventional and organic production in WA.

Others. Data were also obtained from the Agricultural Census of WA, the USDA[14], the Employment Security Department of WA, and other profit and non-profit organizations.

Model Modification

The fruit industry in IMPLAN was modified in order to incorporate conventional and organic apple sectors in the I/O model. The following adjustments were made in the model.

Sectors modification. The fruit sector in the IMPLAN I/O model was separated into two sectors: all fruits except apples, and apples. The apple sector was then divided into conventional apple and organic apple sectors. Conventional and organic apple production methods were separately identified in the model.

Margins and the conversion to I/O accounting. In order to be consistent with standard I/O accounting[15], all expenditures in the enterprise budgets must be presented in terms of producer prices rather than purchaser prices. (Producer price is the price at the farm gate, while purchaser price is the price the consumer pays after transportation and marketing services are added to the producer price.) Thus, margin tables were used to convert the purchaser prices from the enterprise budgets to producer

Table 1. Annual cost per 0.405 ha (1 acre) for the conventional and organic apple sectors, 1997.

Category/item	Conventional	Organic
	----------US$----------	
Variable Cost:		
Custom Soil Prep.	0	0
Trees	0	0
Custom Planting	0	0
Trellis Material	0	0
Tape and Twine	50.00	50.00
Tree Training Material	0	0
Grass Cover Estab.	0	0
Mulch	0	0
Compost	0	0
Landscape Fabric	0	0
Fertilizer	48.91	13.36
Chemicals	670.40	58.44
Beehives	35.00	35.00
Pheromone Dispensers	110.00	110.00
Labor	903.59	1602.76
Custom Picking	500.00	600.80
Custom Hauling	187.50	225.30
Irrig./Electric Charge	168.75	168.75
Equipment Repair	227.74	216.36
Equipment Fuel/Lube	147.37	166.91
Overhead	156.55	166.91
Interest	81.69	90.48
Total Variable Cost	3287.50	3505.07
Fixed Costs:		
Equipment Deprec.	374.72	403.63
Equipment Interest	398.97	429.55
Equipment Insurance	26.53	28.58
Equipment Taxes	69.26	75.38
Land Tax	64.19	64.19
Land Cost	350.00	350.00
Management	250.00	250.00
Estab. Cost Interest	1343.26	1629.14
Total Fixed Cost	2876.93	3230.47
Total Cost	6164.43	6735.54
Value of Production[1]	4015.31	5555.82
Net Returns	(2149.12)	(1179.72)

[1] This value is different from the Glover et al. study because it was calculated by multiplying the average yield per bin by the average apple price per bin where Glover et al. used prices and yield per bin of 1997.
Source: Glover et al.[13]

prices. The final products that producers bought at purchaser prices were separated into transportation, wholesale margin, retail margin, and producer price as is standard practice for I/O analysis. This was done by using information from the IMPLAN margin tables (p. 18, 52 and 274)[12].

The procedure of Willis and Holland[15] was used to convert apple enterprise budgets into a framework consistent with the standard I/O accounting structure. Willis and Holland[15] used six sequential procedures to translate producer enterprise budgets into I/O accounts. Similar procedures using two steps were used in the present study.

The first step was mapping the enterprise budgets into an I/O account framework. This was done by mapping conventional and organic apple budget expenditure in Table 1 into the I/O accounting structure. The second step was converting the enterprise budget's fixed costs into the I/O format presented in Table 1. To do so, three accounts were created[15]: (1) proprietary income, (2) total value added, and (3) total industry outlay (TIO) (Table 2).

The production functions. It may be observed that the total cost is higher than the value of production, which leads to negative net returns (Table 1). In order to account for this in the I/O format, the value of production in Table 1 and TIO in Table 2 should be equal. To make this adjustment, the other property income account was decreased by the amount of negative net return shown in Table 1.

The value added figures in Table 2 were derived as follows: Employee Compensation was taken directly from labor and picking estimates in Table 1, Indirect Business Taxes were calculated using the method of Willis and Holland[15], and the remaining property type income was allocated to Proprietary Income and Other Property Income on the basis of fixed proportions for the fruit sector in the Washington IMPLAN I/O model (20% Proprietary Income and 80% Other Property Income). The above allocation was used for both conventional and organic production.

Finally, it was necessary to calculate the production function technical coefficients. This coefficient was calculated by dividing the individual industries' input purchase in producer price value by the TIO. Moreover, employment numbers, Washington consumption of apples, and foreign export of apples were also incorporated into the model.

On a cost per hectare basis, conventional production requires greater conventional inputs but less labor than organic production (Table 3). The same wage per hour was assumed in both organic and conventional production, and the price premium was assumed for organic production. Organic production requires greater expenditure per unit of land, but generates larger returns to capital and labor. This is due to the organic price premium enjoyed by organic apples. The 3-yr average yield (Bins/Hectare) for organic production was actually 94% of the 3-yr year conventional production yield.

Results and Economic Impacts

When final demand for a particular commodity changes, three types of economy-wide impacts are measured in a Type SAM I/O model: direct, indirect, and induced effects.

Direct effects. Direct effects are the immediate effects within the economy as a result of change in final demand of a particular industry[16]. For example, an increase in final demand for apples of US$1 million will cause the apple sector to produce US$1 million worth of apples.

Indirect effects. Indirect effects are the changes in output or employment of backward-linked industries due to the new demand of the directly affected industry. In the

Table 2. Conventional and organic apple production functions in I/O accounting framework before margining[1].

	Apple industry output			
	Per 0.405 ha (1 acre)		Aggregation	
Sector names	**Conventional**	**Organic**	**Conventional**	**Organic**
	US$			
Inputs				
Tape & Twine	50.00	50.00	10,107,250.00	81,700.00
Fertilizer	48.91	13.36	9,886,911.95	21,830.24
Chemicals	670.40	58.44	135,518,008.00	95,490.96
Beehives	35.00	35.00	7,075,075.00	57,190.00
Pheromone Dispensers	110.00	110.00	22,235,950.00	179,740.00
Custom Hauling	187.50	225.30	37,902,187.50	368,140.20
Irrig/Electric Charge	168.75	168.75	34,111,968.75	275,737.50
Equipment Repair	227.74	216.36	46,036,502.30	353,532.24
Equipment Fuel/Lube	147.37	166.91	29,790,108.65	272,730.94
Total Inputs	1645.67	1044.12	332,663,962.15	1,706,092.08
Value Added				
Employee Compensation	1403.59	2203.56	283,728,700.55	3,600,617.04
Proprietary Income[2]	166.52	433.71	33,661,185.40	708,668.68
Other Property Income[3]	666.08	1734.86	134,664,741.60	2,834,754.70
Indirect Business Taxes	133.45	139.57	26,976,250.25	228,057.38
Total Value Added[4]	2369.64	4511.70	479,010,877.80	7,372,117.80
Total Industry Outlay[5]	4015.31[6]	5555.82[7]	811,674,839.95	9,078,209.88

[1] The table also presents the calculation of revenue per 0.405 ha (1 acre) and the aggregated total for all apple production in WA.
[2] Incomes received by self-employed entrepreneurs. All self-employed incomes reported for federal income tax purposes are counted here.
[3] Earned by corporations rather than sole proprietors.
[4] The sum of employee compensation, other property income, proprietary income, and indirect business taxes.
[5] The sum of individual inter-industry input purchases and value added.
[6] Revenue per acre (0.405 ha) for conventional apple production.
[7] Revenue per acre (0.405 ha) for organic apple production.

Table 3. Cost and productivity.

	Cost per acre (0.405 ha)		Cost per bin		Cost per US$ revenue	
	Conv.	**Organic**	**Conv.**	**Organic**	**Conv.**	**Organic**
	US$					
Intermediate Input Payment	1645.6	1044.12	28.09	19.03	0.41	0.188
Employee Comp. Payment	1403.59	2203.56	23.96	40.16	0.350	0.397
Capital Payment	823.6	2168.57	14.06	39.52	0.205	0.390

above example, an increase of US$1 million worth of apples in final demand of the apple sector will require the chemical and fertilizer industries to increase their output in order to meet the inputs demanded by the directly affected industry[16].

Induced effects. Induced effects are the changes in output of all industries as a result of changes in household consumption generated from the increased household income stemming from the direct and indirect effects of business activity (p. 102)[12].

Two scenarios will be applied for each sector to analyze the economic impact. The first scenario considers the economic impact of conventional and organic industries in terms of an assumed US$1 million change in final demand. The second scenario considers the economic impacts of a change in final demand that corresponds to the value of sales from the output of an assumed 405 ha (1000 acres). The second scenario captures the effect of the price premium on organic production.

Conventional apple sector's output and employment impacts for US$1 million increase in final demand

By assumption, the direct effect was US$1 million. The indirect effect was an increase of US$174,138 (sales) in the rest of the economy (Table 4). Increased final demand for the conventional apple sector also creates jobs directly and

indirectly. For a US$1 million increase in final demand of the conventional apple sector, the direct employment effect was 25.9 jobs and 2.4 jobs were created in the off-farm sectors. Compared to the direct employment effect, the indirect employment effect is relatively small. Thus, for each job created in the conventional apple sector, an additional 0.093 jobs were indirectly generated in the rest of the Washington economy.

The total induced effect of the Type SAM model was US$312,875, resulting in a total impact of US$1,587,013. In other words, for each US$ increase in final demand for conventional apples, sales increased by US$1.587 for the entire Washington economy, including the apple sector. The total employment induced effect was 4.3 jobs, and the total employment effect was 32.5 jobs (Table 4). The employment multiplier number of 1.255 indicates that, for each job created in the conventional apple sector, an additional 0.255 jobs will be created throughout the Washington economy.

Organic apple sector's output and employment effects for US$1 million increase in final demand

Assuming a final demand increase of US$1 million for organic apples, there is a total indirect effect of US$158,295 (Table 4). This is a lower indirect effect than resulted from the same increase in the conventional sector because organic production requires fewer purchased inputs than conventional apple production. This measure, however, does not include labor or employee compensation.

Because organic apple production is more labor intensive, the total employment effect of organic production is greater than that of conventional apple production. The direct employment impact was 29.4 jobs for organic production and 25.9 jobs for conventional production. However, the total indirect employment for organic production was 1.4 jobs, which was lower than for conventional production. Even though the organic apple sector required more direct labor, its input suppliers required less labor because of less input demand from the organic apple sector (Table 4). Under the organic production, other industries in the region experienced a smaller ripple effect. Nevertheless, total labor employment in the region was higher as a result of organic production because it requires more direct labor.

The total induced effect was US$341,164 and the total output (sales) effect was US$1,499,459, resulting in an output multiplier of 1.499. In other words, for each US$ increase in organic apple sector final demand, the total output of the entire WA economy increases US$1.499. Compared to conventional apple production, organic apple production results in a higher total induced effect because of greater labor use even though the total output effect or total output multiplier was lower for organic apples. The increased household income and expenditures generated more induced output from organic production than from conventional production. Since the indirect effect of organic production was less than that from conventional production, however, organic production had a lower total effect. The total induced employment effect was 4.7, while the total employment effect was 35.5 (Table 4).

Table 4. Results summary of impact analysis for conventional and organic apple production.

	Final demand increase in every million US$ Type SAM	Output increase in every 405 ha Type SAM
Conventional apple		
Output (in thousand US$)		
Direct effect	1000.00	4015.31
Indirect effect	174.14	1120.50
Induced effect	312.88	1278.84
Total effect	1587.01	6414.65
Employment (jobs)		
Direct effect	25.9	105.7
Indirect effect	2.4	9.8
Induced effect	4.3	17.5
Total effect	32.5	133
Output multiplier	1.59	1.59
Employment multiplier	1.25	1.25
Organic apple		
Output (in thousand US$)		
Direct effect	1000.00	5555.82
Indirect effect	158.30	879.46
Induced effect	341.16	1895.44
Total effect	1499.46	8330.72
Employment (jobs)		
Direct effect	29.4	163.4
Indirect effect	1.4	7.8
Induced effect	4.7	26
Total effect	35.5	197.2
Output multipliers	1.50	1.50
Employment multipliers	1.21	1.21

In terms of employment impact, the direct and total effects were higher in the organic production than in conventional production. Nevertheless, the indirect effect was higher under conventional production. Counting direct, indirect, and induced effects, production of US$1 million of organic apples creates three more jobs in the Washington economy than US$1 million of conventional apple production.

Conventional apple sector's output and employment impacts for a 405 hectare increase in production

It is appropriate to conduct the analysis on a per unit of land basis because the premium price of organic apples increases their value per unit of output. Looking at economic impacts on a per US$ of sale basis fails to account for this important economic factor.

The direct effect of 405 ha of conventional apples was US$4,015,310, and the indirect effect was US$1,120,502.

The direct employment effect was 105.7 jobs, and the total indirect effect was 9.8 jobs. The total induced effect from the Type SAM model was US$1,278,835, giving a total sales effect of US$6,414,647. The total output multiplier was 1.587, which was the same as in the US$1 million final demand case. The total induced employment effect was 17.5 jobs and the total effect was 133.0 jobs. This says that 405 ha (1000 acres) of conventional apple production will generate 133 jobs throughout the Washington economy. One hundred and six jobs will be on-farm and 27 jobs will be in the rest of the economy.

Organic apple sector's output and employment impacts for a 405 ha increase in production

The total direct and indirect effects were US$5,555,820 and 879,459 respectively. The direct and indirect employment effects were 163.4 and 7.8 jobs respectively. Compared to conventional apple production, the total direct and the total effects were higher for organic apple production than for conventional apple production. For an increase of 405 ha production, the direct employment effect in organic apple production was 163.4 jobs compared to 105.7 jobs in conventional apple production.

The total induced effect of organic apple production was US$1,895,444 and the total effect was US$8,330,723. The total employment-induced effect was 26.0 jobs and the total effect was 197.2 jobs. This compares to 133 jobs under conventional apple production. Of the 197 jobs associated with organic production, 163 of the jobs are on-farm with 34 of the jobs in the rest of the economy (off-farm).

Implications and Conclusions

In this analysis, we set out to do two things: (1) incorporate conventional and organic apple industries into a Washington I/O model, and (2) use the model to measure the impact of organic and conventional products on the Washington economy. Since the analysis provides a detailed picture of economy-wide economic impacts, for both conventional and organic apple sectors, policy makers could use this analysis for economic development planning. For example, the analysis provides economic multipliers for both conventional and organic production systems. These multipliers may be used to estimate how many jobs would be created throughout the economy for a given change in organic apple production in WA. The analysis also shows which production system creates more jobs and income and leads to greater economic sustainability.

The enterprise budgets clearly showed that organic apple production was more labor intensive and more profitable than conventional production. However, organic production also uses less inter-industry inputs than conventional production. All things being equal this would be expected to lead to a smaller economic ripple effect for organic apple production. Nevertheless, the larger direct and induced impacts for organic apple production more than offset the smaller indirect impacts.

Looking at 405 ha of production, while the indirect effect was lower in organic apple production, the induced effect and total effect were higher. This was the case for both sales and jobs. Given the price premium of organic apples, the value of organic production per hectare was higher than conventional production. Also, with organic production, payrolls and proprietor incomes were higher. The result was greater household income and greater induced impact. In terms of secondary effects, the smaller indirect effect of organic production is more than offset by the larger induced effect. Production of organic apples will generate more off-farm ripple effects in the Washington economy than production of conventional apples because of higher value per unit of organic apples, along with greater labor intensity and higher returns to capital. This is true even though the output and employment multipliers for organic production are lower than the respective multipliers for conventional production. In understanding economic impacts, policy makers should not mindlessly concentrate on multiplier magnitudes without considering the individual components embodied in the multiplier.

From this analysis based on a TYPE SAM I/O model, agricultural scientists and policy makers can see for the first time both the direct and secondary effects of both types of apple production on the Washington economy. Assuming the organic premium remains in effect, conversion of conventional to organic apple production would result in a positive total economic impact (total jobs and total sales) in the WA economy.

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Appendix 1: The Leontief I/O Model

The literature related to the I/O model and economic impact analysis dates back to 1758 when the French economist, Francois Quency, published a Tableau Economique tracing inter-industry relationships between agriculture and other industries[17]. The second major development came from another French economist, Leon Walras, who developed a theoretical general equilibrium economic model in the1870s[18]. Wassily Leontief[19] published the first empirical application of the I/O model with an I/O model of the US economy and, in 1970, won the Nobel Prize in economics for his work on I/O analysis.

Leontief's I/O model is a system of linear equations that describes the relationship between purchases of inputs and the sale of output for all industries within an economy. The underlying assumption is that the supply responds to demand[20]. The I/O model is initially developed from the I/O Table which shows sales and purchases by each industry in the economy. To move from the accounting table to an economic model, all industries are assumed to exhibit a fixed proportion production function where all inputs maintain a constant and fixed proportion to output. For example, a 50% increase in output requires a 50% increase in all inputs. With this assumption, we can derive the technical coefficient matrix by dividing the input purchases of a sector (industry) by its total output. This matrix of technical coefficients is known as the A matrix. It represents the production functions of all the industries in the model (economy). Following are the assumptions of the I/O Model[12,21].

1. Final demand is exogenous and supply (output) is endogenous. Therefore, supply is assumed to respond to demand.
2. Each industry is characterized by a fixed-proportion production function or Leontief production function. Inputs must always be combined in fixed proportions. There is no substitution of inputs.
3. Constant returns to scale result in linear production functions. As output increases, all inputs will increase proportionately.
4. There are no supply constraints: it is assumed that the supply of all inputs is unlimited and perfectly elastic.

The I/O model can be derived through the algebraic manipulation of the matrix equations. Derivation of the analytical model can be expressed in equations as follows.

$$X = AX + Y, \tag{1}$$

$$(I - A)X = Y, \tag{2}$$

$$X = (I - A)^{-1}Y, \tag{3}$$

where X = total output (industry sales); I = identity matrix; A = the A matrix or matrix of technical coefficients; Y = final demand.

Equation (1) represents the basic I/O model equation where it simply states that output supply (X) is equal to intermediate demand (AX) plus final demand (Y). Equation (2) rewrites equation (1). Equation (3) solves for X as a function of Y. Equation (3) shows that output (X) is a function of final demand (Y) through the Leontief Inverse

$(I-A)^{-1}$. The $(I-A)^{-1}$ is also called the matrix of the multipliers. This also can be interpreted as:

$$\Delta X = (I-A)^{-1} \times \Delta Y. \quad (4)$$

Equation (4) shows how total industry output (X) will change when final demand changes are made[12,21]. In this study, we estimate changes in total output for all industries (X) in response to an assumed US$1 million change in final demand of the conventional and organic apple sectors.

Appendix 2: Review of the IMPLAN System

IMPLAN is a computer simulation system that is used for constructing regional economic accounts and I/O models to measure regional economic impact[22]. The program was originally developed by the USDA Forest Service[23] and later was supported by Minnesota IMPLAN Group, Inc. The program is widely used by both academic and economic development communities[16,23]. The IMPLAN software system, combined with the IMPLAN database, allows users to construct a detailed (528-industry) transactions table and related intermediate and final demand, value added, and import and export tables for any combination of counties or states in the US. Of these 528 sectors, 468 sectors exist in WA. Moreover, the IMPLAN system also includes inter-industry and inter-sector transaction accounts. With mathematical manipulation of these accounts, the system estimates the employment, output and income changes resulting from changes in final product demand[18].

Book Review

Together At the Table: Sustainability and Sustenance in the American Agrifood System. By Patricia Allen. 2004. Penn State Press, University Park, PA. 260 p. $45.00, ISBN 0-271-02473-9, hardcover.

The central role played by government in agriculture sets it apart from most other sectors in advanced economies. In recent years this system of government involvement has come under attack from both the left and right sides of the political spectrum. Accusations leveled at the US agrifood system, include concerns about surplus production, food quality and safety, and the degradation of the natural environment resulting from intensive agriculture. In her book *Together at the Table*, Patricia Allen argues that a recent crisis of the modern US agrifood system, which for years has been governed by an iron triangle of traditional commodity interests, has resulted in the emergence of alternative agrifood movements such as the sustainable agriculture movement and the community food security movement.

Allen argues that these movements have made enormous strides over the past decade or so, but have received limited attention from social scientists who have been more interested in the vagaries of agribusiness. Allen seeks to redress this neglect in *Together at the Table* by investigating the core assumptions and positions of these movements, their success, in moving towards a more sustainable food system and their influence on mainstream agrifood institutions. The book begins with a discussion of the deficiencies of the modern US agrifood system, followed by a discussion of the alternative agrifood movement response to these challenges. Then Allen considers how these responses have been institutionalized. Subsequently, she explores the emergent and residual discourses of the movements and how some movement discourses reflect the ideologies of the mainstream food system. The final chapters of the book focus on the deficiencies of the movements in terms of their power relations and inclusiveness, and how these movements can overcome some of their internal contradictions.

This study represents a unique contribution to the study of the US agrifood system, having a dual emphasis on movements concerned with the production (sustainable agriculture movements) and consumption (community food security movements) of food. Another innovative feature of this study is the focus on the discursive rather than the material politics of the agrifood system. The author examines a discursive shift in the mainstream institutions of the agrifood system toward a sustainable agricultural model, even though commodity agriculture continues to receive material support. The author presents a critical analysis of the movements behind this discursive shift, arguing that they have largely neglected some crucial features of a truly sustainable agrifood system, such as social justice, while continuing to adhere to regressive agrarian and liberal economic ideologies. Thus, while she recognizes the potential for alternative agrifood movements to radically alter the US food system, she also draws the reader's attention to the structural and ideological barriers these movements have to overcome before this potential can be realized.

The author draws on multiple sources of evidence in order to capture how the constituents of these movements construct their worldview and position themselves in relation to the contemporary agrifood system. She successfully integrates secondary, survey, interview and textual data. Most of the evidence marshaled by the author relates to the Californian agrifood system. The alternative agrifood movement in California is among the most advanced and progressive in the country. However, the use of California as a case study also presents problems when the author wishes to speak on developments in the wider US agrifood system. It may be the case that California is too unique a case to allow the author to speak confidently about changes occurring at the national level or in other parts of the US. Thus, additional case study material from alternative agrifood movements in the Mid-West or North-East might have strengthened the author's argument.

Together at the Table has significant potential to enhance the understanding of agrifood governance for government officials and other policymakers. The book also provides critical direction for activists in agrifood movement organizations. However, as is the case with many volumes that attempt to cross the line between scholarly and applied social science, there is a risk that the non-specialist reader could get lost in the academic language. Throughout the publication, Allen introduces a multitude of social science concepts, ranging from discourse, ideology, social ecology, organic and traditional intellectuals, etc. This can at times be overwhelming.

That said, there is no doubt that *Together at the Table* is a unique and important contribution to the study of agrifood system governance in the US and how it is influenced by alternative agrifood movements. In this volume, Allen has presented a detailed analysis, a critical reflection and a call to action on the contemporary agrifood system that should interest scholars, activists and decision makers alike.

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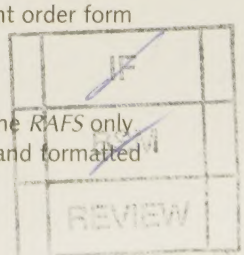

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